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ABSTRACT

To facilitate the discussion of national education standards, this workbook extracts examples of education standards from eight documents that describe what students should be taught, or what they should know or be able to do in various subjects. These examples illustrate and document some existing standards, and should help policy makers sharpen their thinking about standards as they help people develop common concepts of standards. The examples are: (1) curriculum and evaluation standards for school mathematics, issued by the National Council of Teachers of Mathematics in 1989; (2) standards in physical and information sciences and engineering defined by a project of the American Association for the Advancement of Science in 1989; (3) a science framework for California public elementary schools and secondary schools issued by the state in 1990; (4) the Advanced Placement Examination in United States History of the College Board; (5) objectives for the 1972-73 Science Assessment of the National Assessment of Educational Progress (NAEP); (6) Toronto Benchmarks, a standards communicating system issued by the Toronto (Canada) Board of Education in 1991; (7) objectives for the 1988 NAEP Geography Assessment; and (8) the national mathematics curriculum of England and Wales established in 1989. Test materials for each example are included. An appendix contains some comments about educational standards by T. H. Fisher of the Florida Department of Education. (SLD)

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Information for

National Standards for Education: What They Might Look Like

A Workbook

Policy Information Center
EDUCATIONAL TESTING SERVICE

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Preface

Policy Information "Workbooks" are issued from time to time as resource materials for people working on national education goals and education reform. The last such publication, "Information for National Performance Goals For Education: A Workbook," was issued in 1989 while the national goals were being formulated. This Workbook is directed to people considering, discussing, or formulating "national education standards."

The idea of *national* standards in the United States is a new one, an idea that would have been untenable only a few years ago. As a result, we lack a common vocabulary to facilitate the discussion -- the word "standards" means different things to different people. This "workbook" extracts examples of education standards from eight documents that describe what students should be taught, or what they should know or be able to do in various subjects. We hope that these examples will: 1) illustrate and document some existing "standards," 2) help policy markers sharpen their thinking about "standards" by reviewing and reacting to them, and 3) help people develop common concepts of "standards."

Paul E. Barton
Director
ETS Policy Information Center
March, 1992

Acknowledgments

We wish to thank the organizations that published the eight documents used in this workbook for their permission to reproduce materials from them. Archie Lapointe, Steve Koffler, Ina Mullis, Nancy Mead, Dale Carlson, and Tom Fisher helped identify these examples of standards. Carla Cooper did the desktop publishing. Albert Benderson did the editing.

Introduction

In one way or another a central conversation in education reform has revolved around "standards." In the last few years it has become common and acceptable to call for "national standards," a concept that had almost no support a decade ago. The development of national standards in education has become a principal objective of the National Education Goals Panel, and these domestic standards are intended to lift us to "World Class" standards.

Yet the discussions remain very general, and when these conversations last very long, it usually becomes clear that not all parties to the conversation have the same idea in mind as to what does, and what does not, constitute standards of the kind they want America to have.

Several ideas seem to exist about what standards are:

- A clear statement of what students should know and be able to do at particular points in their schooling
- Performance levels that students should be able to attain or demonstrate, an idea that begins to blend "standards" with "assessment"
- Specification and definition of the necessary and desirable core of knowledge in a subject to be taught
- Achievement of a particular point on a performance scale or a passing score on a test[1]

We have not had the years of experience with national level educational reform and leadership that would produce some common understanding of what it means to have national standards and what they might look like. But we have had some experiences that might help inform the discussion.

Some people are aware of a few notable examples of standards in individual academic fields, but few have actually *read* the appropriate material. Who in these discussions in national forums has actually read the new mathematics standards issued by the National Council of Teachers of Mathematics? Who has read the "objectives" booklets of the National Assessments of Educational Progress? Who has read a syllabus of the College Board's Advanced Placement Program? The existence of these sources is relatively well known in the circles discussing standards, but they are specialized documents, likely to be in few offices of the generalists, educators, and policy officials engaged in such discussions.

Thus this volume. It is simple in its purpose, with no admonitions as to how to do standards. It has no researcher's conceptual schemes of the education system, and no exhortations to action. What follows are eight examples drawn from existing documents. They are reproduced here for three purposes:

1. To make accessible the experience we do have with careful efforts to write down what students should know and be taught.

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[1] For a discussion of how the word "standards" is used different ways in one state, see the letter from Tom Fisher, Director of Testing in Florida, to the Policy Information Center, in the Appendix.

2. To help the parties to the discussion sharpen their own concepts of what standards should be like, by reading these and reacting to them.

3. To aid the discussion by helping people develop common images of what they mean by standards, and what others mean.

None of these eight approaches are offered as recommendations, either as to their form, the levels of proficiency they imply, or the content they embody. All are respectable efforts for the purposes they were designed to serve.

The examples are drawn from

1. The Curriculum and Evaluation Standards for School Mathematics, issued by the National Council of Teachers of Mathematics in 1989 (page 17)

2 A Panel Report of Project 2061, of the American Association for the Advancement of Science, covering Physical and Information Sciences and Engineering, issued in 1989 (page 35)

3. The Science Framework for California Public Schools, Kindergarten through Grade Twelve, adopted by the California State Board of Education in 1990 (not reproduced in this volume, but a description and example is on page 6 and 7).

4. Advanced Placement (AP®), United States History, a program of the College Board (page 73)

5. The Science Objectives for the 1972-73 Science Assessment of the National Assessment of Educational Progress (page 103)

6. Toronto Benchmarks, issued by the Toronto Board of Education in 1991 (page 115)

7. The Geography Objectives for the 1988 Geography Assessment of the National Assessment of Educational Progress (page 125)

8. The National Mathematics Curriculum in England and Wales, ordered into use in 1989 (page 141)

1. Curriculum and Evaluation Standards For School Mathematics

These standards, issued by the National Council of Teachers of Mathematics, reflect a broad consensus about what students should know and be able to do. Following three years of development, they were issued in March of 1989. They have been endorsed by 15 organizations and supported by 25 other organizations; 20 organizations have agreed to serve as allies of the National Council in its effort to improve teaching and learning.

The introduction to the standards for grades K-4 states that they represent a:

> "a vision for school mathematics built around five overall curricular goals for students to achieve: learning to value mathematics, becoming confident in one's own ability, becoming a mathematical problem solver, learning to communicate mathematically, and learning to reason mathematically. This vision addresses what mathematics is, what it means to know and do mathematics, what teachers should do when they teach mathematics, and what children should do when they learn mathematics."

There are 13 curriculum standards for grades K-4, 13 for grades 5-8, and 14 for grades 9-12. There are also 14 standards for evaluation. We have reproduced standards 1 through 7 of the K-4 standards.

Workbook materials are drawn from *Curriculum and Evaluation Standards for School Mathematics*, National Council of Teachers of Mathematics, 1989.

Example

"Standard 3: Mathematics as Reasoning

In grades K-4, the study of mathematics should emphasize reasoning so that students can --

- draw logical conclusions about mathematics;
- use models, known facts, properties, and relationships to explain their thinking;
- justify their answers and solution processes;
- use patterns and relationships to analyze mathematical situations;
- believe that mathematics makes sense"

2. Physical and Information Sciences and Engineering (Project 2061)

In 1985, the American Association for the Advancement of Science launched Project 2061, named for the year Haley's Comet will return. The purpose of the project is to achieve major reforms in science, mathematics, and technology education. An overall report, *Science for All Americans,* was issued in 1989 when implementation commenced.

Also as part of the project's initial phase, five panels each issued a report in a particular science domain. These five reports stand on their own and also served as the basis for *Science for All Americans.* The purpose of Phase I was to establish "a conceptual base for reform by defining the knowledge, skills, and attitudes all students should acquire as a consequence of their total school experience from kindergarten through high school." In Phase II, these reports are being translated by teams of educators into "blueprints for action" and will result in a variety of curriculum models. In Phase III there will be a nationwide effort to turn the blueprints and models into educational practice.

The five panels were given ground rules for preparing their reports:

- Focus on scientific significance
- Apply considerations of human significance
- Begin with a clean slate
- Ignore the limitations of present-day education
- Identify only a small core of essential knowledge and skills
- Keep in mind the target population -- all students

The report extracted from this volume, *Physical and Information Sciences and Engineering,* was written by George Bugliarello. The other reports are:

- *Biological and Health Sciences*
- *Mathematics*
- *Social and Behavioral Sciences*
- *Technology*

Project 2061 is carrying the development of standards another step. Its Fall 1991 newsletter reports:

> Team members, with input from other educators, are now working out a common set of reasonable expectations for students at elementary, middle, and high school. In 1992, a complete draft of SFAA [Science for All Americans] "benchmarks," perhaps with sample indicators of progress, will be reviewed by representatives of education and scientific organizations, schools, and the public before appearing....

However, the existing panel reports are useful now to help form concepts of what standards can be like. The Physical and Information Sciences and Engineering attempted "to identify key concepts...that -- in our opinion -- a high school graduate should know."

Workbook materials are drawn from *Physical and Information Sciences and Engineering*, A Project 2061 Panel Report, by George Bugliarello, American Association for the Advancement of Science, 1989.

Example

"---there are some key concepts specific to each discipline or group of disciplines---that all high school students should have the opportunity to explore and understand, at least to some degree."

a key concept:

"• Atomic Nuclei Undergo Changes

Relevant Items: Radioactivity, nuclear energy..., the transmutation of elements, and the synthesis of new elements.

Comments: These changes are related to the basic structure of matter. It is essential that citizens be familiar with some manifestations and effects of these changes, such as x-rays, luminous watches, nuclear magnetic resonance, nuclear power, and solar radiation."

3. Science Framework For California Public Schools, Kindergarten Through Grade Twelve

California issued "Science Framework" in 1990. The 1990 Science Framework "addresses...(1) What is important to learn? and (2) How can we ensure that all students have the opportunity to learn it?" This new Science Framework conveys the importance of a "theoretic approach to science" and follows the themes approach urged by *Science for All Americans*, the report of Project 2061.

This is an excellent example of how standards can evolve, from a general statement of how and what should be taught in science, to adaptation and specification by a state education system. The Framework is used to drive the state's testing system, the California Assessment Program. Educators use it to

"(1) establish guidelines and provide direction to help districts revise their curricula, evaluate their programs, assess their instruction, and develop instructional strategies;

(2) serve as a resource for preservice and in-service education of teachers and administrators;

(3) provide direction to publishers for the development of textbooks and instructional materials and to reviewers for selecting instructional materials and testing programs; and

(4) make information on curricula available to parents and the general public."

Science Framework is organized, therefore, around the *themes* of science: "Themes are the big ideas of science, larger than facts and concepts; they link the theoretical structures of the various disciplines... [the themes are] (1) energy; (2) evaluation; (3) patterns of change; (4) scale and structure; (5) stability; and (6) systems and interactions."

It is a 220 page volume. The large section on "The Content of Science" consists of three parts, Physical Sciences, Earth Sciences, and Life Sciences. The example below is from the Physical Sciences section.

The full title is *Science Framework for California Public Schools, Kindergarten Through Grade Twelve*, adopted by the California State Board of Education, and published by the California Department of Education, Sacramento, 1990.

Example

"C-1 What is Motion? What are some basic kinds of motion? How is motion described?

Grades Three Through Six

A moving object is one that changes position as time passes. Speed is a measure of the distrance traveled (change in position) by the object during a certain time interval; it is, for example, the distance moved in one second or in one hour. The units of speed will be determined by the units used to measure distance and time. For example, a speedometer provides a quick reading of the speed of a car in miles per hour. The motion of an object at a certain speed also has a direction. Direction can be specified in various ways: up/down, left/right, compass directions, and so forth."

4. Advanced Placement (AP™)
United States History

The Advanced Placement (AP) Program, sponsored by the College Board and administered by ETS, is a cooperative education effort linking secondary schools and colleges. It now consists of 29 college-level courses and examinations that are offered in nearly 10,000 high schools in the U.S., throughout Canada, and in 63 other countries. Participating colleges grant credit or appropriate placement, or both, to students performing satisfactorily on the AP Examinations. The example used here is United States History.

The AP Program does not provide a specific curriculum or texts. Schools and teachers create the curriculum and select the texts and teaching materials. What AP does provide is a fairly detailed "course description," which generally covers the equivalent of a full-year college course. Although the course descriptions are designed primarily for teachers, department heads, and curriculum coordinators, they can also serve as useful guides for students who wish to prepare for the examinations through independent study. In most subjects the program provides:

- An AP Course Description
- A Teachers Guide to AP courses
- A complete recent examination
- A description of how the exam was graded

The course description has sometimes been described as a syllabus. It sets the "standards" for the course in terms of the content material to be taught and the level at which it is taught. The examinations contain either an essay or problem-solving section and another section consisting of multiple-choice questions. In June of each year, the examinations are graded by over 2,100 college and secondary school teachers.

Workbook materials are drawn from the May 1991 *Advanced Placement United States History Course Description*. They include:

- The "Guide for Advanced Placement, United States History Test Coverage" (pp 4-17)
- Examples of multiple-choice questions (pp 22-25)
- Examples of free-response, essay questions (pp 35-44)

Examples

"31. Kennedy's New Frontier; Johnson's Great Society

A. New domestic programs

1. Tax cut
2. War on poverty
3. Affirmative action

B. Civil rights and civil liberties

1. Black Americans: political, cultural, and economic roles
2. The leadership of Martin Luther King, Jr.
3. Resurgence of feminism
4. The New Left and the Counterculture
5. Emergence of the Republican party in the South
6. The Supreme Court and the *Miranda* decision

C. Foreign Policy

1. Bay of Pigs
2. Cuban missile crisis
3. Vietnam quagmire"

5. The Science Objectives for the 1972-73 Science Assessment of the National Assessment of Educational Progress (NAEP)

The 1972-73 Science Assessment was conducted during the fourth year of assessments by NAEP. The objectives prepared for that assessment are a good example of what NAEP was able to do in its early years when it was well funded.[2] These objectives described quite specifically what students should know and be able to do.

For example, under "understand and apply laws (principles)," the objectives stated, "they [students] should be able to apply them in order to solve problems in familiar situations and in situations different from those in which the laws (principles) were learned." The four examples included, "(2) Apply some principles related to the conceptual scheme of genetic continuity." For these examples, the level of understanding/application was described for ages 9, 13, 17, and adult. At age 17, the student was expected to give examples "of mutation and the role that natural barriers play in the evolutionary process."

The NAEP objectives booklet says, "Objectives define a set of goals which are agreed upon as desirable directions in the education of children." These goals must be acceptable to the scholars in the discipline, to most educators, and to thoughtful lay citizens. Further, "National Assessment objectives must also be a clear guide to the actual development of assessment exercises. Thus, most assessment objectives are stated in such a way that an observable behavior is described."

The 1972-73 objectives built upon the objectives set for the 1969-70 initial assessment of science. Seven pages of the booklet are devoted to listing the people involved in writing the objectives, either in meetings and conferences, or through the mail.

NAEP, from its early days, has been innovative in many areas, including the development of new ways to assess students. The 1972-73 Science Assessment fielded a particularly large set of hands-on tasks, involving the use of science equipment. These were abandoned as resources devoted to NAEP began to dwindle. A few examples follow:

- **Demonstrating a simple experiment**

  Seventeen-year-olds were asked to conduct an experiment to find out how two light bulbs were wired together. In order to do the experiment, they were given two circuit boards with batteries attached, four loose light bulbs, and a workbook.

- **Demonstrating principles using a model**

  Students (age 13 and 17) were asked to demonstrate two basic geological concepts--faulting and folding of the earth's crust. Each student was given two foam-rubber blocks placed side by side along with instructions to demonstrate faulting and folding.

---

[2] By the mid-1980s, the NAEP grant had dwindled to under $4 million per year, about a fourth, in real dollars, of the funding levels reached in the early 1970s.

- **Conducting a simple test**

  Students (age 13 and 17) were asked to determine the volume of a small rock. Each student was given a small nonporous rock, a 12 inch rule, a graduated cylinder, spring scales, water in a jar, a piece of string, and a set of instructions.

Workbook materials are drawn from *Science Objectives for the 1972-73 Assessment*, National Assessment of Educational Progress, Education Commission of the States.[3]

Examples

"b. Develop scientific hypotheses

For example, is able to pose hypotheses that would be most relevant in solving a problem; is able to suggest data that would be pertinent to a problem.

Age 9	Demonstrates that effects occur under reproducible conditions; formulates simple explanations for natural phenomena.
Age 13	Understands the nature of a scientific hypothesis: proposes a simple explanatory hypothesis for a natural phenomenon.
Age 17	Considers a wide variety of factors in the formulation of a hypothesis: understands that in the formulation of any given hypothesis some factors are important and others are extraneous: develops a hypothesis with a degree of explicitness and attention to relevant factors that would render the hypothesis useful and testable."

---

[3] These materials are now available through Educational Testing Service.

6. Toronto Benchmarks

Toronto Benchmarks are a departure from all conventional approaches to the establishment of standards and the evaluation of student achievement against them. While it is a system for student evaluation, it is also a system for *communicating* standards to students, teachers, principals, and parents. It is also a system that is integrated with instruction, and it is not a "test."

Benchmarks are a set of tasks that allow students to demonstrate what they can do at different levels of proficiency. Videos were used to record the performances of a large random sample of Toronto Board students. These videos were used in the holistic scoring of student perormances, thus displaying students knowledge and skills in more ways than in paper and pencil assessment.

Benchmarks, in communicating standards, begin with the written "Key Objectives" of the Ontario Ministry of Education and Toronto Board Guidelines. The objectives are highly specific. For example, one objective for sixth-grade mathematics asks students to:

- Estimate capacity and volume with appropriate degree of precision
- Demonstrate measurement skills involving the use of various instruments

Benchmark tasks incorporate the "Key Objectives." Beyond that, the tasks "were also designed to resemble normal, complex, open-ended and life-like classroom activities." Several tasks may be used to incorporate a set of objectives. In the case of the objectives above, the first task required that students estimate, then measure, how much water containers of different sizes would hold. Then the students measured the water. Students were videotaped doing these tasks.

The Benchmark Program "facilitates communication, openness, and sharing because samples of students' performances (both videotape and print) provided along with the scoring criteria elucidate the objectives and standards of the educational system." The materials are not "secretive tests" but serve as "reference materials to be studied by teachers, parents and students." The tasks included in the Benchmarks libraries in Grades 3, 6 and 8 Language Arts and Mathematics serve as models for the development of additional classroom tasks. The criteria for judging performances may be applied to similar tasks.

Workbook materials are drawn from *Benchmarks: The Development of a New Approach to Student Evaluation*, Sylvia Larter, Ph.D, Toronto Board of Education, 1991 ($15).

For more information, contact: Marilyn M. Sullivan
Superintendent-Curriculum
Toronto Board of Education
155 College Street
Toronto, Ontario, M5T1P6

Example

"M6-8 Grade 6 Mathematics Video | Number 8 of 27 Benchmarks

Key Objectives from the Ontario Ministry of Education and Toronto Board Guidelines

- Estimate capacity and volume with appropriate degree of precision
- Demonstrate measurement skills involving the use of various instruments

POURING WATER
Estimating and Measuring Capacity and Volume

Several tasks were designed to formulate this Benchmark.

A. Capacity

This activity is demonstrated on the videotape.

The first task required that students estimate, then measure, how much water a large container (3L) would hold. This was followed by asking students to estimate and then measure how much water a small container (250 mL) would hold. For measuring each container students were provided with a basin of water and a calibrated litre cylinder.

Students who did well on these tasks gave close estimates and measured accurately and efficiently. They demonstrated a good grasp of the concepts and skills involved. They showed confidence and enjoyed and the challenge presented by the tasks."

© Toronto Board of Education

7. The Geography Objectives for the 1988 Geography Assessment, National Assessment of Educational Progress (NAEP)

For the first time ever, NAEP assessed Geography at the 12th grade and 17-year-old level, in 1988. The assessment was funded by the National Geographic Society.

NAEP's procedures, as usual, included the initial appointment of a Learning Area Committee, which set to establish the "objectives" of education in geography. In issuing its report, the Learning Area Committee for Geography made a statement typical of such NAEP committees:

> Although [the objectives] define areas pertinent to the teaching of geography as well to the development of questions to assess students' geographic understanding, the objectives are not intended as a complete or definitive specification of curriculum topics. Rather, they provide an overview of learning outcomes.

In the early 1980s the geography community engaged in a effort to define the discipline as it should be taught in the public schools, based on extensive involvement and consultation. The result was the *Guidelines for Geographic Education* (1984), prepared by the Joint Committee on Geographic Education of the National Council for Geographic Education and the Association of American Geographers. The Learning Area Committee drew upon the guide when establishing its objectives.

Workbook materials are drawn from *Geography Objectives, 1988 Assessment*, The Nation's Report Card (NAEP), Educational Testing Service.

Example

> **"Climatology and Meteorology**
>
> Studying climatology and meteorology, and their reciprocal relationships with environmental features, provides another basis for understanding physical geography. For example, the burning of fossil fuels and the destruction of tropical rain forests contribute to an increase in the carbon dioxide concentration in the atmosphere which, in turn, contributes to an increase in the earth's average temperature (known as the greenhouse effect). This climatic change may also initiate or exacerbate other environmental consequences.
>
> Students should be able to understand:
>
> a) How earth/sun relationships affect climate (e.g., heating, wind, and ocean currents) and time (e.g., days and seasons), including differential effects for the hemispheres.
>
> b) The reciprocal relationships among climate, soils, and vegetation.
>
> c) Various atmospheric pressure conditions as they relate to local and global patterns of wind and precipitation."

8. The National Mathematics Curriculum in England and Wales

In a massive education reform effort, England adopted a mandatory National Curriculum in 1989. While some changes have been made recently, this curriculum is still in force pretty much as it was described in the extract reproduced here.

The curriculum is expressed in a set of Attainment Targets, each one with ten levels of proficiency and Programmes of Study. Each level of the Attainment Targets is illustrated by an example of what the students should be able to do. The Programmes are the means by which the Targets are to be achieved.

The materials do not look much different than others in this volume. They differ in that they have the force of law in England and Wales.

Workbook materials are drawn from *Mathematics in the National Curriculum,* Department of Education and Science and the Welsh Office, London: Her Majesty's Stationery Office, 1989.

Example

"Attainment Target 1:
Using and applying mathematics

Pupils should use numbers, algebra and measures in practical tasks, in real-life problems, and to investigate within mathematics itself.

Level	Statements of Attainment	Example
	Pupil should:	
1	• use materials provided for a task.	*Compare objects to find which is the longest, tallest, etc.*
	• talk about own work and ask questions.	*Talk about a set of objects being compared; ask questions such as: 'Which is the longest pencil?'*
	• make predictions based on experience.	*Use a balance to compare objects; predict which of two objects will be the heavier.*
	* * *	
9	• design, plan and carry through a mathematical task to successful conclusion.	*Design a wire frame lampshade with the design showing clearly the length of wire and area of material required.*
	• state whether a conjecture is true, false or not proven; define and reason; prove and disprove and use counter-examples; use symbolisation; recognise and use necessary and sufficient conditions.	*Devise and test a statement about the minimum surface area for a cylinder of fixed volume."*

Curriculum and Evaluation Standards for School Mathematics

STANDARD 1:
MATHEMATICS AS PROBLEM SOLVING

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In grades K-4, the study of mathematics should emphasize problem solving so that students can—

- ***use problem-solving approaches to investigate and understand mathematical content;***
- ***formulate problems from everyday and mathematical situations;***
- ***develop and apply strategies to solve a wide variety of problems;***
- ***verify and interpret results with respect to the original problem;***
- ***acquire confidence in using mathematics meaningfully.***

Focus

Problem solving should be the central focus of the mathematics curriculum. As such, it is a primary goal of all mathematics instruction and an integral part of all mathematical activity. Problem solving is not a distinct topic but a process that should permeate the entire program and provide the context in which concepts and skills can be learned.

This standard emphasizes a comprehensive and rich approach to problem solving in a classroom climate that encourages and supports problem-solving efforts. Ideally, students should share their thinking and approaches with other students and with teachers, and they should learn several ways of representing problems and strategies for solving them. In addition, they should learn to value the process of solving problems as much as they value the solutions. Students should have many experiences in creating problems from real-world activities, from organized data, and from equations.

In the early years of the K–4 program, most problem situations will arise from school and other everyday experiences. When mathematics evolves naturally from problem situations that have meaning to children and are regularly related to their environment, it becomes relevant and helps children link their knowledge to many kinds of situations. As children progress through the grades, they should encounter more diverse and complex types of problems that arise from both real-world and mathematical contexts.

When problem solving becomes an integral part of classroom instruction and children experience success in solving problems, they gain confidence in doing mathematics and develop persevering and inquiring minds. They also grow in their ability to communicate mathematically and use higher-level thinking processes.

Discussion

Classrooms with a problem-solving orientation are permeated by thought-provoking questions, speculations, investigations, and explorations; in this environment, the teacher's primary goal is to promote a problem-solving approach to the learning of all mathematics content. The following two examples illustrate this meaning.

A lesson designed to develop the characteristics of parallelograms can be approached from a problem-solving perspective. The teacher, who has a collection of quadrilaterals like the ones shown in figure 1.1, has the children discover the teacher's rule for sorting the shapes. One rule is to have all parallelograms in one loop and all nonparallelograms in the other.

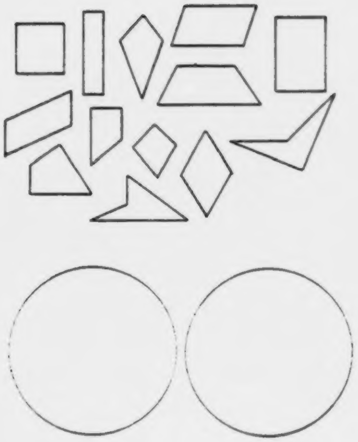

Fig. 1.1

In turn, each child picks a shape and decides in which loop to put it. The teacher says yes or no as each student places a shape. Throughout the process, the children are asked to think about the common characteristics of the shapes in each loop; after all shapes are placed, these common characteristics are discussed. As a result, the children learn to define parallelograms and name their characteristics in the context of a thought-provoking activity.

Basic subtraction facts also can be presented in a problem-solving setting.

Each child is asked to put 13 small counters under one hand and, without looking, to move 6 of them into view. The teacher asks, "Can you figure out how many counters are still under your hand?" The children are invited to share their solution strategies. Responses might include the following:

There are six over here [outside]; six more would be twelve, so there must be seven left.

You have six here. Four more make ten and three more make thirteen; four and three are seven. Seven are left.

The class then discusses solving subtraction problems by "adding on."

Once again, the mathematical ideas have originated with the children rather than the teacher, in an inquiry-oriented manner.

Computer software also is a significant component of a comprehensive problem-solving program. Many excellent software packages enable children to develop and apply problem-solving strategies in geometry, logical reasoning, classification, measurement, fractions and decimals, and other mathematical content.

A major goal of problem-solving instruction is to enable children to develop and apply strategies to solve problems. Strategies include using manipulative materials, using trial and error, making an organized list or table, drawing a diagram, looking for a pattern, and acting out a problem.

Consider the following problem:

I have some pennies, nickels, and dimes in my pocket. I put three of the coins in my hand. How much money do you think I have in my hand?

This problem leads children to adopt a trial-and-error strategy. They can also act out the problem by using real coins. Children verify that their answers meet the problem conditions. Follow-up questions can also be posed: "Is it possible for me to have four cents? Eleven cents? Can you list all the possible amounts I can have when I pick three coins?" The last question provides a challenge for older or more mathematically sophisticated children and requires them to make an organized list of possible coin combinations, perhaps like the one in figure 1.2.

pennies	nickels	dimes	total value
0	0	3	30
0	1	2	25
0	2	1	20
0	3	0	15
1	0	2	21
⋮	⋮	⋮	⋮

Fig. 1.2

The initial conditions can be altered to include quarters:

I have six coins worth 42 cents; what coins do you think I have? Is there more than one answer?

A vital component of problem-solving instruction is having children formulate problems themselves. Children can write variations for problems previously explored, word problems that correspond to a number sen-

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Representing, talking, listening, writing, and reading are key communication skills and should be viewed as integral parts of the mathematics curriculum. Probing questions that encourage children to think and explain their thinking orally or in writing help them to understand more clearly the ideas they are expressing.

Representing is an important way of communicating mathematical ideas at all levels, but especially so in K–4. Representing involves translating a problem or an idea into a new form. Translations of this type often are used by adults and children as they converse with others. Children might draw diagrams, for example, to express an idea or viewpoint in an alternative format that might be more comprehensible to the listener. The act of representing encourages children to focus on the essential characteristics of a situation. Representing includes the translation of a diagram or physical model into symbols or words. A child should be able to examine a set of two bundles of ten and four units each and match the set with the symbol 24. (See fig. 2.1.) Since representing is central to learning and using mathematics, it is important to provide many such experiences for children. Any of the following materials would be useful: base-ten blocks, straws that can be bundled in sets of ten, connecting cubes, or loose counters that must simply be grouped together to show the tens.

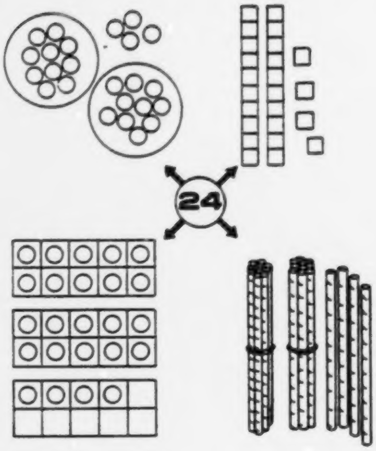


Fig. 2.1

Representing is also used in translating or analyzing a verbal problem to make its meaning clear. The problem in figure 2.2 involves a part-whole comparison, but many children who have not had enough experience in modeling such situations or who do not actively model this situation fail to recognize its structure.

If a bag contains 3 white balls and 1 blue ball, what is the probability of pulling out a blue ball?

Fig. 2.2

Some students simply use the numbers 1 and 3 to arrive at an answer of 1/3. A concrete representation or diagram will help children to correctly identify that four balls can possibly be drawn.

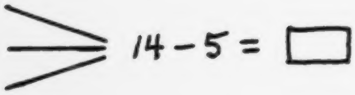
Communicating by talking and listening is also very important. When small groups of children discuss and solve problems, they are able to connect the language they know with mathematical terms that might be unfamiliar to them. They make sense of those problems. The use of concrete materials is particularly appropriate because they give the children an initial basis for conversation. Such occasions also permit the teacher to observe individual students, to ask probing questions, and to note or attend to any conceptual difficulties individual students might be experiencing. The following discussion activity would help children see how several problems that appear to be different in fact share the same underlying structure: 14 − 5 = ☐. The children would be given counters to model each problem.

With your group, use counters of different colors to model each of these problems and then discuss how the problems are alike or different.

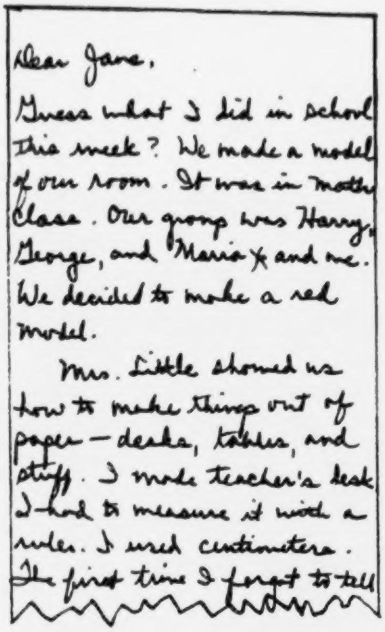
Maria had some pencils in her desk. She put 5 more in her desk. Then she had 14. How many pencils did she have in her desk to start with?

Eddie had 14 helium balloons. Several of them floated away. He had 5 left. How many did he lose?

Nina had 14 seashells. That was 5 more than Pedro had. How many seashells did Pedro have?



As children talk about mathematics, it is important to keep in mind that what appears at first to be an incorrect response may be, in fact, an inability to communicate. Of primary importance is the value children derive from reflecting on their responses.



Dear Jane,
Guess what I did in school
this week? We made a model
of our room. It was in math
class. Our group was Harry,
George, and Maria X and me.
We decided to make a real
model.
Mrs. Little showed us
how to make things out of
paper—desks, tables, and
stuff. I made teacher's desk
I had to measure it with a
ruler. I used centimeters.
The first time I forgot to tell

Fig. 2.3

Writing is a communication skill that has been used too infrequently in mathematics. It is particularly useful because it allows a child who is uncomfortable in oral situations to express understanding in a less public forum. After children have solved a problem, they can write their answer in sentence form, which helps them exhibit a knowledge of the problem's place in the real world and clarify their thinking.

Students can write a letter to tell a friend about something they have learned in mathematics class. This type of activity allows the students to consider mathematics for a new purpose. If letters are exchanged, then students learn from the thought processes of their peers. See figure 2.3.

Having students keep journals in mathematics class is another way to facilitate communication and give them an opportunity to reflect on their learning. A journal can be a form of free expression about the mathematics studied, or children can be asked to respond to directions such as these: Tell me what you thought were the hardest and easiest parts of today's lesson and why.

Children can also create their own stories or books about mathematics. Many schools have a "young authors" program that encourages children to develop an idea into a book to be shared with parents or classmates. This activity is within the reach of fourth graders and can include mathematics topics as options for development.

Many children's books present interesting problems and illustrate how other children solve them. Through these books students see mathematics in a different context while they use reading as a form of communication. Some of the books most directly linked to mathematics give children insights into the history of mathematics and the development of mathematical ideas. Materials children write themselves can be part of a reading activity and shared with class members. Mathematics texts have not often been viewed as sources of reading material, but taking this perspective can add a valuable dimension to students' learning. Many schools are making efforts to include expository reading as an important part of reading instruction. Mathematics texts and other mathematics reading materials should certainly be included in these efforts.

Children learn from one another as they communicate. Encouraging them to represent, talk and listen, write, and read facilitates meaningful learning. Attending to students' communications about their thinking also gives teachers a rich information base from which they can make sound instructional decisions.

STANDARD 3:
MATHEMATICS AS REASONING

In grades K–4, the study of mathematics should emphasize reasoning so that students can—

- ***draw logical conclusions about mathematics;***
- ***use models, known facts, properties, and relationships to explain their thinking;***
- ***justify their answers and solution processes;***
- ***use patterns and relationships to analyze mathematical situations;***
- ***believe that mathematics makes sense.***

Focus

A major goal of mathematics instruction is to help children develop the belief that they have the power to do mathematics and that they have control over their own success or failure. This autonomy develops as children gain confidence in their ability to reason and justify their thinking. It grows as children learn that mathematics is not simply memorizing rules and procedures but that mathematics makes sense, is logical, and is enjoyable. A classroom that values reasoning also values communicating and problem solving, all of which are components of the broad goals of the entire elementary school curriculum.

A climate should be established in the classroom that places critical thinking at the heart of instruction. Both teachers' and children's statements should be open to question, reaction, and elaboration from others in the classroom. Such a climate depends on all members of the class expressing genuine respect and support for one another's ideas. Children need to know that being able to explain and justify their thinking is important and that how a problem is solved is as important as its answer. This mind-set is established when children have opportunities to apply their reasoning skills and when justifying one's thinking is an expected component of problem discussions.

Discussion

This standard's descriptor, "Mathematics as Reasoning," was purposely chosen. Mathematics *is* reasoning. One cannot do mathematics without reasoning. The standard does not suggest, however, that formal reasoning strategies be taught in grades K–4. At this level, mathematical reasoning should involve the kind of informal thinking, conjecturing, and validating that helps children to see that mathematics makes sense. Consistent use of such questions as "Why do you think that's a good answer?" or "Do you think that you would get the same answer if you used these other materials?" conveys to the children the importance of critical thinking and establishes a spirit of inquiry.

Children should be encouraged to justify their solutions, thinking processes, and conjectures in a variety of ways. Manipulatives and other physical models help children relate processes to their conceptual underpinnings and give them concrete objects to talk about in explaining and justifying their thinking. Observing children interact with objects in this way allows teachers to reinforce thinking processes and evaluate any possible misunderstandings.

Creating and extending patterns of manipulative materials and recognizing relationships within patterns require children to apply analytical and spatial reasoning. See figure 3.1.

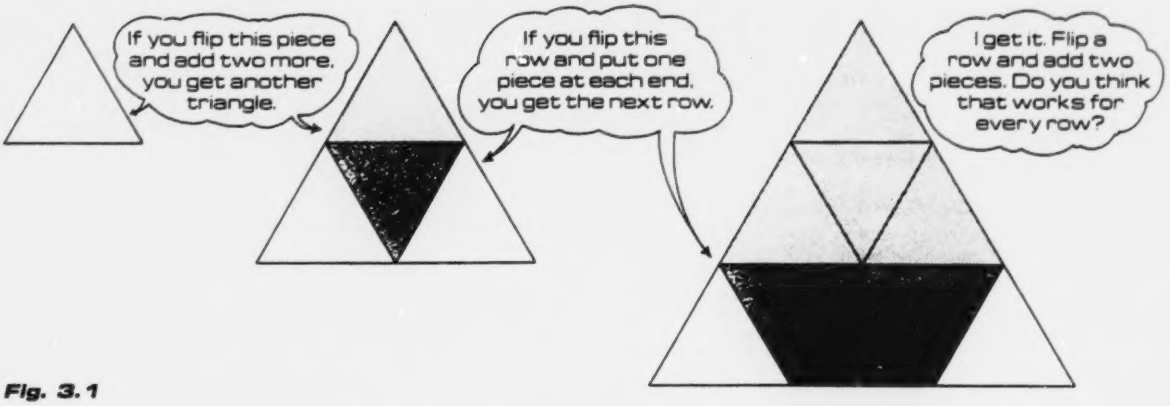

If you flip this piece and add two more, you get another triangle.
If you flip this row and put one piece at each end, you get the next row.
I get it. Flip a row and add two pieces. Do you think that works for every row?

Fig. 3.1

The kindergartner who created the attribute block pattern in figure 3.2 proudly announced that she had four patterns in one.

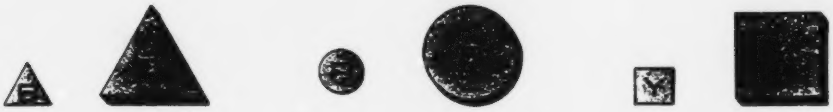


Fig. 3.2

Pointing to each element in turn, she said, "See, there's triangle, triangle, circle, circle, square, and square. That's one pattern. Then there's small, large, small, large, small, and large. That's the second pattern. Then there's thin, thick, thin, thick, thin, and thick. That's the third pattern. And the fourth pattern is blue, blue, red, red, yellow, and yellow. The triangles are blue, the circles are red, and the squares are yellow."

Children also reason analytically when they identify valid arguments. When the class considers $35 - 19 = \square$, the teacher can ask questions like these: "Do you think it would help to know that $35 - 20 = 15$?" "How would it help to think of 19 as $15 + 4$?" "Would it help to count on from 19 to 35?" It is also important for children to recognize invalid arguments, such as "Would it help to count backward from 19?"

Many problems can be solved by the process of elimination, in which children systematically select the items that satisfy one or more given conditions by eliminating those that do not. "Who Am I?" and "What Am I?" games require this kind of thinking in both creating and solving problems. See figure 3.3.

What Am I?

I have 3 or 4 sides.
All my angles are equal.
My sides are not all equal.

Who Am I?

I am an even number.
I am more than 20 and less than 30.
I am not 25.
The sum of my digits is 8.

Fig. 3.3

These activities also give students a chance to encounter informally several important ideas, such as the language of logic, the use of a counterexample, and distinctions between relevant and irrelevant information. The use of *and*, *or*, and *not* in these activities illustrates the language of logic. The reasoning in the "What Am I?" game is based on a counterexample involving known properties of an equilateral triangle. "If I have three sides, I am a triangle. But I can't be a triangle because all triangles with equal angles have equal sides and I do not have equal sides." The clue "I am not 25" in the "Who Am I?" game is irrelevant because another clue identifies the number as even: Clearly the number cannot be 25, and this information is of no value in solving the problem.

Applying reasoning skills to discover a relationship they have not recognized before can be an exhilarating experience for children, as a group of third graders learned. They were using a calculator to explore number relationships when they noticed that if one addend is decreased by any amount and another addend is increased by the same amount, their sum remains the same. After checking their conjecture with a variety of numbers, they recorded it as a discovery so that it could be shared with the rest of the class. See figure 3.4

$$\begin{array}{r} 19 \\ +5 \\ \hline 24 \end{array} \quad \begin{array}{r} 18 \\ +6 \\ \hline 24 \end{array} \quad \begin{array}{r} 16 \\ +8 \\ \hline 24 \end{array} \quad \begin{array}{r} 13 \\ +11 \\ \hline 24 \end{array}$$

$$\begin{array}{r} 123 \\ +76 \\ \hline 199 \end{array} \quad \begin{array}{r} 120 \\ +79 \\ \hline 199 \end{array} \quad \begin{array}{r} 100 \\ +99 \\ \hline 199 \end{array}$$

Fig. 3.4

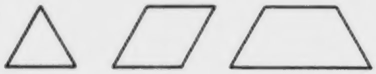
Our Discovery: When you add, if you make one part bigger and the other part gets the same amount smaller, you always get the same answer.

One member of the group thought the relationship should "work" for subtraction, too, until a partner showed several cases for which it did not work.

These children applied analytical reasoning and developed and tested conjectures, one of which they rejected on the basis of counterexamples.

An informal introduction to proportional reasoning is appropriate at the K–4 level. The problem-solving context of the following example also reinforces many of the reasoning processes already discussed.

I have a shape that can be covered with twelve of these triangles. How many of these parallelograms would I need to cover my shape? How many of these trapezoids will cover my shape?



Since the problem concerns physical objects, the students can recognize visually that two triangles cover a parallelogram, that three triangles cover a trapezoid, and that the entire shape can be covered by six parallelograms or by four trapezoids. To justify their conclusion, the children can use twelve triangles to make a shape and check to see whether it can be covered by six parallelograms or four trapezoids. Students should also realize that some shapes composed of twelve triangles cannot be covered by parallelograms or trapezoids.

Mathematical reasoning cannot develop in isolation. As illustrated in this discussion, the ability to reason is a process that grows out of many experiences that convince children that mathematics makes sense.

STANDARD 4: MATHEMATICAL CONNECTIONS

In grades K–4, the study of mathematics should include opportunities to make connections so that students can—

- ***link conceptual and procedural knowledge;***
- ***relate various representations of concepts or procedures to one another;***
- ***recognize relationships among different topics in mathematics;***
- ***use mathematics in other curriculum areas;***
- ***use mathematics in their daily lives.***

Focus

This standard's purpose is to help children see how mathematical ideas are related. The mathematics curriculum is generally viewed as consisting of several discrete strands. As a result, computation, geometry, measurement, and problem solving tend to be taught in isolation. It is important that children connect ideas both among and within areas of mathematics. Without such connections, children must learn and remember too many isolated concepts and skills rather than recognizing general principles relevant to several areas. When mathematical ideas are also connected to everyday experiences, both in and out of school, children become aware of the usefulness of mathematics.

A classroom in which making connections is emphasized exhibits several notable characteristics. Ideas flow naturally from one lesson to another, rather than each lesson being restricted to a narrow objective. Lessons frequently extend over several days so that connections can be explored, discussed, and generalized. Once introduced, a topic is used throughout the mathematics program. Teachers seize opportunities that arise from classroom situations to relate different areas and uses of mathematics. Children are asked to compare and contrast concepts and procedures. They are helped to construct bridges between the concrete and the abstract and between different ways of representing a problem or concept. Learning and using mathematics are important aspects of the entire school curriculum.

Discussion

When children enter school, they have not segregated their learning into separate school subjects or topics within an academic area. Thus, it is particularly important to build on the wholeness of their perspective of the world and expand it to include more of the world of mathematics. This can be done in many ways, both within and outside the realm of mathematics.

Young children understand the underlying structure of many numerical problems and use counting to solve them. It is important to tie these conceptual ideas to more abstract procedures such as adding and subtracting. If conceptual understandings are linked to procedures, children will not perceive of mathematics as an arbitrary set of rules; will not need to learn or memorize as many procedures; and will have the foundation to apply, re-create, and invent new ones when needed. For example,

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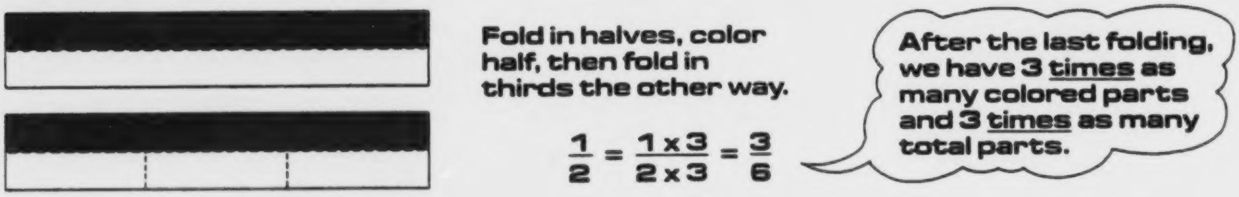
if children are asked to fold paper and describe the process, they will understand why the procedure "multiplying the numerator and denominator by the same number" yields the same ratio in an equivalent fraction. See figure 4.1.



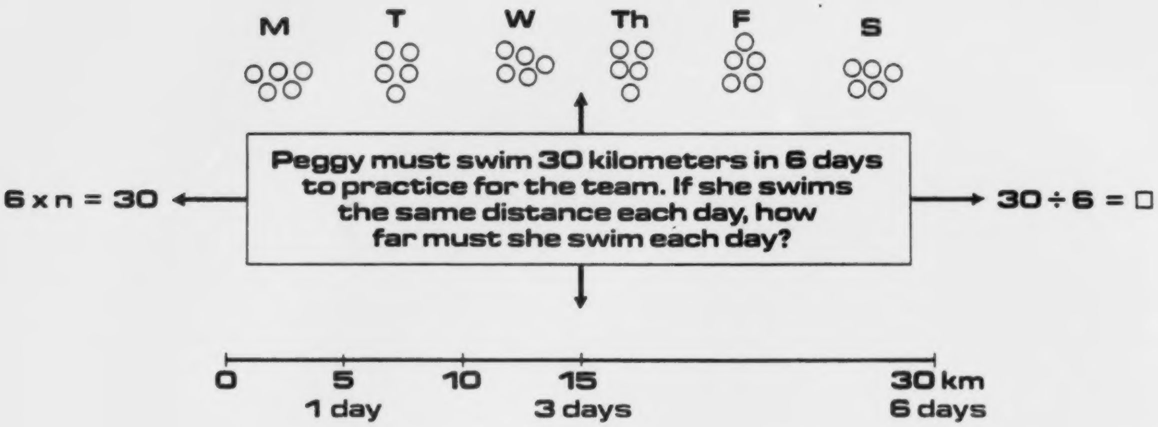
Fold in halves, color half, then fold in thirds the other way.

$$\frac{1}{2} = \frac{1 \times 3}{2 \times 3} = \frac{3}{6}$$

After the last folding, we have 3 times as many colored parts and 3 times as many total parts.

Fig. 4.1

Many concrete and pictorial models of concepts and procedures are available, and children need to create relationships among them and determine how each can be represented with symbols. For example, young children need to make the connection between seven toy cars, seven counters, seven tally marks, and the symbol 7. Older children need to understand the similarity between cutting a rectangle into four equal parts and sharing a bag of cookies among four friends and why the parts in each situation are called fourths. They need to see different representations of the same problem situation, as in figure 4.2.



Peggy must swim 30 kilometers in 6 days to practice for the team. If she swims the same distance each day, how far must she swim each day?

Fig. 4.2

Children tend to think of mathematics as computation. One way to dispel this incorrect notion is to offer them more experiences with other topics; even so, unless connections are made, children will see mathematics as a collection of isolated topics. Only through extended exposure to integrated topics will children have a better chance of retaining the concepts and skills they are taught. For example, measurement situations should continually be part of the program, rather than introduced briefly in isolated lessons. The following activity integrates geometry with measurement.

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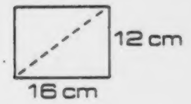
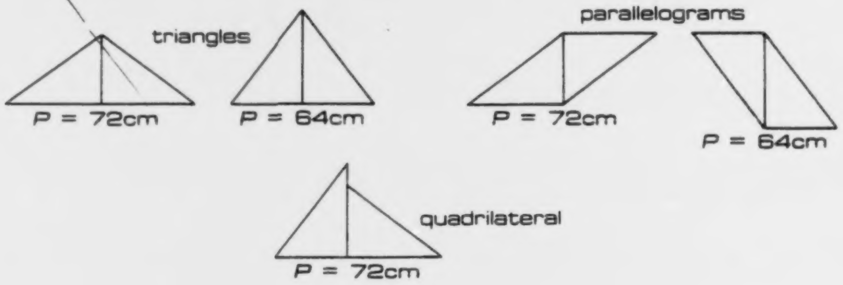
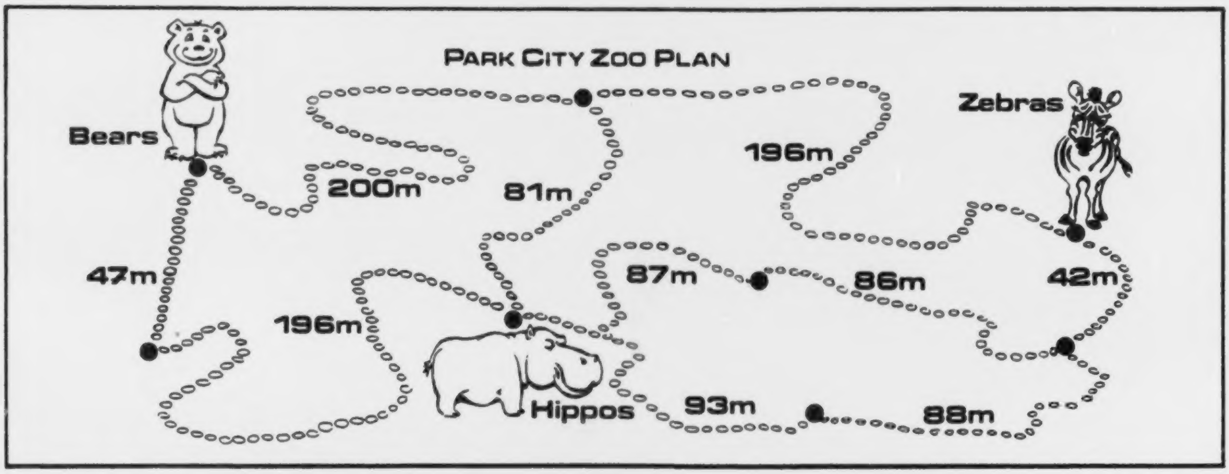


Cut a 12-by-16-cm rectangle on a diagonal as shown. What geometric shapes can you make? Which one has the shortest perimeter?


triangles
P = 72cm
P = 64cm
parallelograms
P = 72cm
P = 64cm
quadrilateral
P = 72cm

Similarly, addition practice can be placed in the context of measuring as children solve for the distances between cages at a zoo (see fig. 4.3).


PARK CITY ZOO PLAN
Bears
Zebras
Hippos
200m
81m
196m
47m
87m
86m
42m
196m
93m
88m

Find the shortest distance from the:

bears to the hippos ____

zebras to the bears ____

hippos to the zebras ____

zebras to the hippos ____

Fig. 4.3

Another connection children can explore is that between solutions to open number sentences and graphing, as shown below.

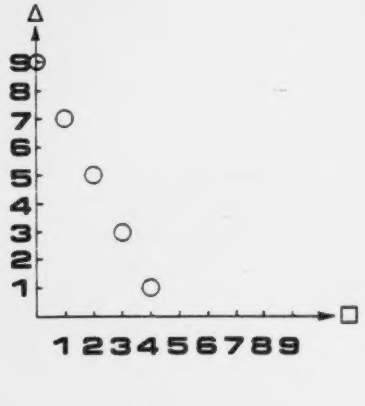
□ + □ + Δ = 9

Try □ = 1

1 + 1 + Δ = 9

Δ must be 7

2 + 2 + 5 = 9
3 + 3 + 3 = 9
4 + 4 + 1 = 9
0 + 0 + 9 = 9



◆ ◆ ◆ ◆ ◆ ◆ ◆ ◆

The K–4 program is rich with opportunities to use mathematics in other subject areas as well as to use other subjects in mathematics. This is especially true with science, but with a little imagination connections can be made to all areas. For example, the communication standard (Standard 2) calls for the integration of language arts as children write and discuss their experiences in mathematics. As children solve problems in mathematics classes, they can be learning about other countries and cultures. As children measure how far they can jump, they use mathematics in physical education. As children do art projects, they use geometry and measurement.

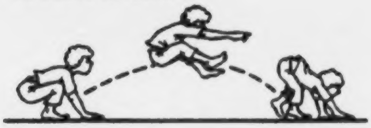
Social Studies

What is the tallest building in Japan?
How tall is it?
Write a sentence comparing its height to the height of the Sears Tower in Chicago.

Physical Education

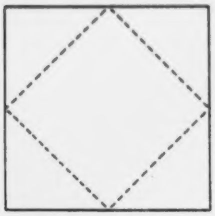
Measure how far you can go in three jumps.

One frog jump.
Start and end on
hands and feet.

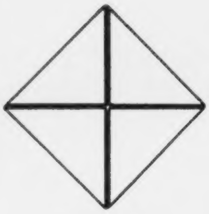


Art

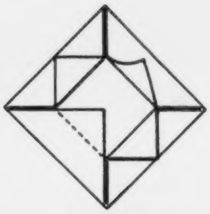
Make the following picture frame for your miniature drawing.



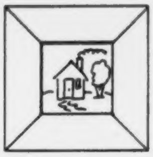
Cut a 20-cm
square.
Find midpoints
of the sides.



Fold flaps
back.
Find midpoints
of the sides.



Fold flaps
back to
midpoints.



Fold flaps
under and
glue picture
in frame.

All too often, children come to believe that mathematics is an academic exercise that occurs only in schools, whereas solving problems outside of school is different. Many believe that it is not mathematics to explore the meaning of one-third by sharing a pitcher of milk equally among three people; to count on a clock face how long until it is time to go to a friend's house; or to figure 100 ÷ 4 by thinking, "Four quarters make a dollar, so it's 25," or "It's 100 divided by 2 and 2 again." Mathematical methods exist to solve these problems in an efficient manner, but, at times, these are not as satisfactory as the informal ways. Students need to see when and how mathematics can be used, rather than be promised that someday they will use it.

STANDARD 5: ESTIMATION

In grades K–4, the curriculum should include estimation so students can—

- ***explore estimation strategies;***
- ***recognize when an estimate is appropriate;***
- ***determine the reasonableness of results;***
- ***apply estimation in working with quantities, measurement, computation, and problem solving.***

Focus

Estimation presents students with another dimension of mathematics; terms such as *about, near, closer to, between,* and *a little less than* illustrate that mathematics involves more than exactness. Estimation interacts with number sense and spatial sense to help children develop insights into concepts and procedures, flexibility in working with numbers and measurements, and an awareness of reasonable results. Estimation skills and understanding enhance the abilities of children to deal with everyday quantitative situations.

From children's earliest experiences with mathematics, estimation needs to be an ongoing part of their study of numbers, computation, and measurement. It is important that children learn a variety of methods of estimating, such as the front-end strategy for computation and the chunking procedure for measurement. They also need to develop reasoning, judgment, and decision-making skills in using estimation.

Instruction should emphasize the development of an estimation mind-set. Children should come to know what is meant by an estimate, when it is appropriate to estimate, and how close an estimate is required in a given situation. If children are encouraged to estimate, they will accept estimation as a legitimate part of mathematics.

Discussion

When children enter school, they are accustomed to estimating. They know that they are almost six years old, that they are a little shorter than a brother or sister, that a carton of milk can fill more than three glasses, and when it is about noon. This experiential knowledge provides a foundation for further development in estimating quantities. Consider the following example: As a referent, children can be told that the set at the left in figure 5.1 has ten balls. Without counting, they can be asked to quickly classify the other sets as fewer than ten, about ten, or more than ten.

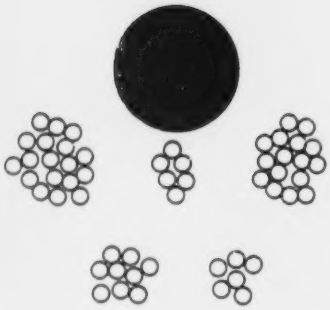


Fig. 5.1

Children should also estimate larger quantities, such as the number of seeds in a pumpkin, beans in a bag, or Valentine candies in a jar. For larger quantities, it is usually more appropriate to use a referent set having 50 or 100 items.

Several important considerations in estimating quantities should be remembered. When checking estimates, a teacher can reinforce place-value ideas by having the children place the estimated items in groups of ten and then in hundreds whenever possible. It is also important for the teacher and the children to identify a range for "good estimates." Further, it should be emphasized that estimates that happen to be exact are no better than other estimates within the identified range; the goal is an approximation, not the exact number. Finally, children should always check their initial estimates and then make additional ones so that they can use the feedback to refine their estimating skills.

A particularly good estimating activity involving measuring uses interlocking cubes. Using a stick of ten cubes as a referent, children estimate how many cubes long a work table is, for example. Then they make a "train" of cubes as long as the work table and break the train into sticks of ten to check their estimates. See figure 5.2.

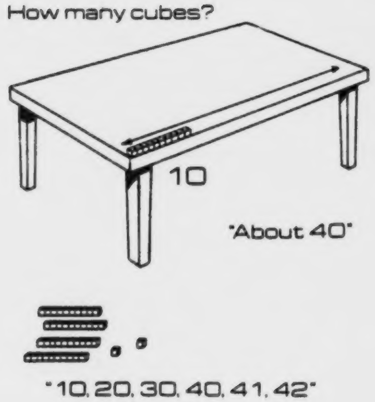
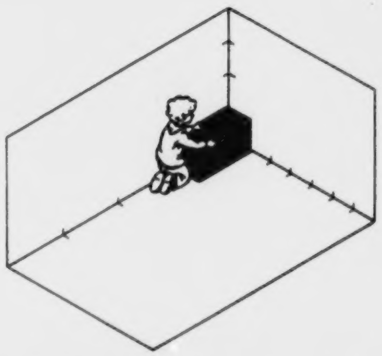


Fig. 5.2

Another measurement-and-estimating activity illustrates the process of chunking. In the task in figure 5.3, children estimate the number of boxes necessary to fill the classroom. A child mentally lines up seven boxes along one edge of the floor and uses them as a unit, or a "chunk," to estimate the total number of boxes.



"I think seven boxes will fit along the floor; then I can do that three more times to cover the floor, that's 4 × 7 = 28, then four layers in all, that's 4 × 28 = 112."

Fig. 5.3

Children also should be taught specific strategies to aid them in *computational* estimation. A child who needs to evaluate 243 + 479 might estimate by thinking, "200 and 400 is 600, 43 and 79 is over 100, so the sum is a little more than 700." This is "front-end estimation." Another way of estimating is this: "243 is just under 250, 479 is just under 500, so the sum is less than 750." This is a flexible use of "rounding" for estimation or selecting "nice" numbers that are easy to work with. It is useful to discuss various strategies and to help students develop their own strategies. For example, a student adept at mental computation could estimate 243 + 479 in this way: "24 + 48 (tens) is 72 (tens) so the sum is about 720." Continual emphasis on computational estimation helps children develop creative and flexible thought processes and fosters in them a sense of mathematical power.

Estimation is especially important when children use calculators. If they need to compute 4783 ÷ 13, for example, a quick estimate can be found by using "compatible numbers." In this case, 4783 is about 4800 and 13 is about 12, so 4783 ÷ 13 is about 4800 ÷ 12. The dividing can be done mentally, since 48 and 12 are "compatible numbers" for division. Thus, 4783 ÷ 13 is about 400. This rough estimate provides children with enough information to decide whether the correct keys were pressed and whether the calculator result is reasonable. Such uses of estimation reduce the incidence of errors with calculators, decrease the mindless use of calculators for computation, and contribute to children's development of number and operation sense.

Children often find that estimation skills are useful in their daily lives. Many children know when it is appropriate to estimate and how close an estimate should be, as the following anecdote indicates. Three children huddled together in a shopping mall, discussing the purchase of some clothing. One held a newspaper advertisement, another a calculator. Two children picked items from the ad and the third entered the appropriate prices into the calculator. In considering the calculator result, one of the children reasoned, "The total cost can't be more than $50 because two shirts cost $14 each; that's less than $30, and the pants cost $17.99." Classroom instruction on estimation should help children develop a similar estimation mind-set so they can use good judgment and logical reasoning to make decisions in their daily lives.

STANDARD 6: NUMBER SENSE AND NUMERATION

In grades K–4, the mathematics curriculum should include whole number concepts and skills so that students can—

- ***construct number meanings through real-world experiences and the use of physical materials;***
- ***understand our numeration system by relating counting, grouping, and place-value concepts;***
- ***develop number sense;***
- ***interpret the multiple uses of numbers encountered in the real world.***

Focus

Children must understand numbers if they are to make sense of the ways numbers are used in their everyday world. They need to use numbers to quantify, to identify location, to identify a specific object in a collection, to name, and to measure. Furthermore, an understanding of place value is crucial for later work with number and computation.

Intuition about number relationships helps children make judgments about the reasonableness of computational results and of proposed solutions to numerical problems. Such intuition requires good number sense. Children with good number sense (1) have well-understood number meanings, (2) have developed multiple relationships among numbers, (3) recognize the relative magnitudes of numbers, (4) know the relative effect of operating on numbers, and (5) develop referents for measures of common objects and situations in their environments.

Children come to understand number meanings gradually. To encourage these understandings, teachers can offer classroom experiences in which students first manipulate physical objects and then use their own language to explain their thinking. This active involvement in, and expression of, physical manipulations encourages children to reflect on their actions and to construct their own number meanings. In all situations, work with number symbols should be meaningfully linked to concrete materials. Emphasizing exploratory experiences with numbers that capitalize on the natural insights of children enhances their sense of mathematical competency, enables them to build and extend number relationships, and helps them to develop a link between their world and the world of mathematics.

If children are to develop good number concepts, considerable instructional time must be devoted to number and numeration. Children's experiences with numbers are most beneficial when the numbers have meaning for them. A variety of place-value tasks that assess children's thinking can be used to identify those numbers that have meaning to individual students; traditional numeration tasks are not good indicators of children's understanding. Teachers can also provide exploratory experiences with larger numbers, but symbolic tasks with numbers should not be presented in isolation and should not be emphasized until the numerals have been carefully linked to concrete materials and children understand the major concepts.

◆ ◆ ◆ ◆ ◆ ◆ ◆ ◆

Discussion

For children to use both single-digit and multidigit number ideas fluently, written symbols should be linked to physical models and oral names. See figure 6.1.

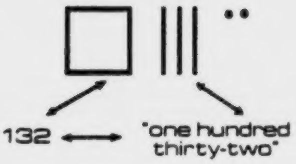
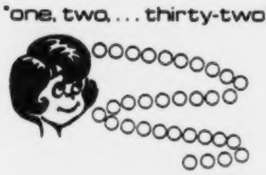


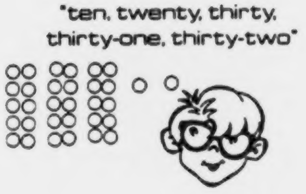
Fig. 6.1

Counting skills, which are essential for ordering and comparing numbers, are an important component of the development of number ideas. Counting on, counting back, and skip counting mark advances in children's development of number ideas. However, counting is only one indicator of children's understanding of numbers.

Understanding place value is another critical step in the development of children's comprehension of number concepts. Prior to formal instruction on place value, the meanings children have for larger numbers are typically based on counting by ones and the "one more than" relationship between consecutive numbers. Since place-value meanings grow out of grouping experiences, counting knowledge should be integrated with meanings based on grouping. Children are then able to use and make sense of procedures for comparing, ordering, rounding, and operating with larger numbers.

The following activity encourages children to coordinate their counting and grouping skills to develop beginning place-value ideas. Two children each are given the same number of counters, in this example, thirty-two. One child counts her counters by ones; the other groups his counters by tens and then counts by tens and ones. The children then are asked to compare and discuss their results.




"ten, twenty, thirty, thirty-one, thirty-two"

The next two tasks help determine a child's place-value knowledge.

"Count these loose chips . . . [25]. Could you write that?" [25] The teacher circles the digit 5 and asks, "Does this part of your 25 have anything to do with how many chips you have?" She repeats the action, this time circling the digit 2. Children with good place-value knowledge will match the "5" with five chips and the "2" with twenty chips, and they may even group the twenty chips into two groups of ten chips. [Fig. 6.2]

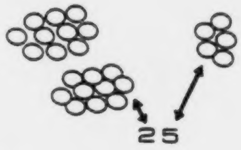


Fig. 6.2

"Here are 256 beans. How many piles of 10 beans could you make?" [Fig. 6.3]

Fig. 6.3

Number sense is an intuition about numbers that is drawn from all the varied meanings of number. It has five components:

1. *Developing number meanings.* This includes the cardinal and ordinal meanings of numbers.

2. *Exploring number relationships with manipulatives.* For example, the composition and decomposition of sets of objects enables children to understand 7 as shown in figure 6.4. Similarly, they understand that 50 is 5 tens, 2 twenty-fives, or 4 tens and 10 ones.

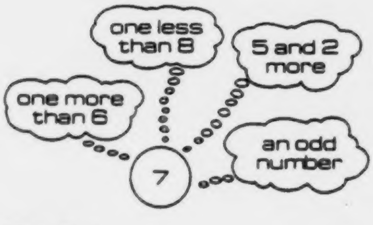


Fig. 6.4

3. *Understanding the relative magnitudes of numbers.* For example, 31 is large compared to 4, about the same size as 27, about half as big as 60, and small compared to 92. Counting by ones rapidly to 100 or 1000 on a calculator helps establish the relative sizes of these numbers.

4. *Developing intuitions about the relative effect of operating on numbers.* This interaction is discussed further in Standard 7, "Concepts of Whole Number Operations," and in Standard 8, "Whole Number Computation."

5. *Developing referents for measures of common objects and situations in their environment.* For example, it is unrealistic for a fourth-grade child to be 316 cm tall or to weigh 8 kg, a loaf of bread doesn't cost $117, and the teacher is not ninety-six years old. A knowledge of reasonable ranges for such measures provides a basis for judging reasonableness of results.

The following classroom example (fig. 6.5) focuses on the first two components of number sense, the meaning of 5 and relating 5 to its component parts.

"Make some designs using five toothpicks in each. Use numbers to tell me how your design is built from the toothpicks."

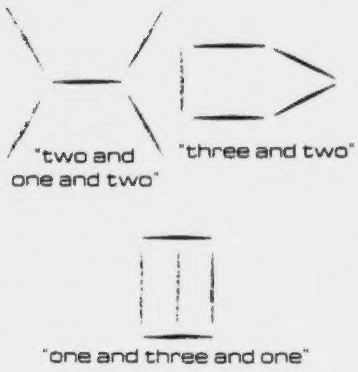
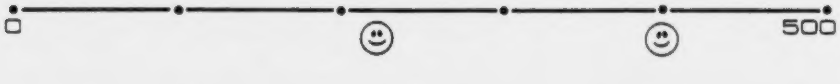


Fig. 6.5

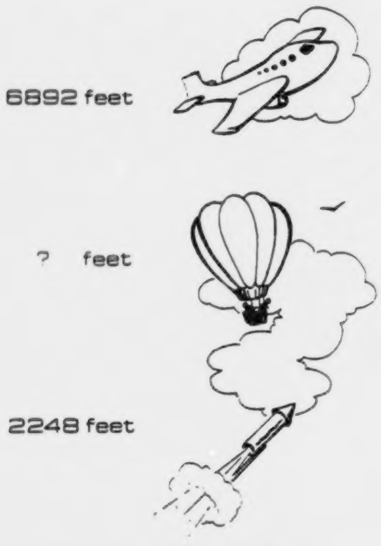
The "Guess My Number" example below helps children develop number-sense ideas regarding the relative magnitudes of larger numbers.

The teacher tapes five metersticks, marked in centimeters, end to end along the front of the room. The left endpoint is labeled 0 and the right endpoint 500. One student (the selector) silently selects a number between 0 and 500, and the others try to guess it.



If the first child guesses 400 and the selector says "Too high," then that child points to the 400 location. If the next child guesses 220 and the selector says "Too low," then that child points to the 220 mark. Guesses continue until the secret number is guessed. The two children pointing initially at 220 and 400 move closer together with each guess, always bracketing the range of possibilities.

The activity in figure 6.6 focuses on relative magnitudes for even larger numbers.



"About how high is the balloon?"

Fig. 6.6

Physical and Information Sciences and Engineering (Project 2061)

SECTION 5

UNIFYING CONCEPTS

The task of teaching the physical and information sciences and engineering in the elementary and secondary schools can be facilitated by focusing on concepts that are common to all aspects of the subjects and often may be useful in the life sciences and the social sciences. Indeed, as an alternative to the traditional disciplinary approach, one can envision teaching all the sciences as well as engineering in an interdisciplinary fashion, by teaching a set of unifying concepts and their meaning in the various traditional disciplines.

What may be most useful unifying concepts is to a considerable extent a matter of choice. Here, we suggest four key concepts, complemented by a number of other general concepts that often cut across them. It is our hope that these key and general concepts will be taken only as examples, and that our suggesting them will not be viewed as advocacy of a new orthodoxy.

KEY UNIFYING CONCEPTS

The four key unifying concepts we suggest by way of example are those of materials, energy, information, and systems. They are all strongly interrelated. For example, there is no material without energy (bonding energies, nuclear energy, etc.); energy is needed to modify materials; information is needed to know how to manipulate and save materials and energy; a system requires the exchange of information among its components, and often of materials or energy as well.

Within each of these four concepts, we can focus on some aspects of general interdisciplinary utility. The depth to which this is done should be left to the teacher. The essential point is that it is possible to introduce the unifying concepts at any desirable level of complexity, according to the grade and skills of the student, and that even in their simplest formulation, such concepts provide us with useful and powerful tools to understand the world around us—be it natural or human-made.

The Concept of Materials

Under the concept of materials, one could include the following topics:

- The definition of materials, and their various manifestations solids and fluids [both liquids and gases]) and uses.

- The properties of materials (for example, density, heat capacity, thermal conductivity, and atomic number, as well as properties that impart strength, cohesion, fluidity, or transparency) and their role in both how we understand nature and how we modify it (for example, by creating new materials with new properties).

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- The conservation of materials, unless transformed into energy (for example, we cannot really get rid of waste, the key factor in the environmental damage wreaked by consumer-oriented and heavily populated societies).

- The transformations from material to material and from material to energy, or vice versa (a process involving an understanding of the atomic and molecular structure considered in physics and chemistry).

The Concept of Energy

The following topics could be included under the concept of energy:

- The definition of energy and its various manifestations (heat, gravitational, bonding, electromagnetic, etc.) and uses.

- Fields, gradients, and potentials (for example, why we slide downhill and why we get an electric shock).

- The conservation of energy, including mass as an equivalent form of energy (mass is energy).

- The transformations among various forms of energy (again, to be related to atomic and molecular structure); and the conversion between rest mass and kinetic energy (with the total mass—that is, energy—remaining constant).

- Energy transfer (for example, heat transfer), degradation, and entropy.

- Efficiency and its theoretical and practical limits.

As an example of the use of a unifying concept, we can follow the transformation of a given amount of energy that originates in a given form. One example might be fossil energy. We could trace its origin in the sun and its conversión by photosynthesis and biological decay to its extraction in the form of oil (hydrocarbons) from a well. Its path could be followed further as it is refined to gasoline or diesel fuel and then burned in the engine of a car, in part transformed into useful work and in part dissipated through road friction and aerodynamic resistance, and then returned to the environment in the form of heat and air pollution. (It is important to stress that the combustion of the hydrocarbons in the engine produces carbon dioxide and other by-products—as is the case with the burning of other natural materials such as wood or coal—that contribute in a major way to air pollution.) A similar example of an energy path is the transformation, utilization, and dissipation of energy contained in food.

The Concept of Information

The following topics could be included under the concept of information:

- The formal definition of information and its relation to probability (for example, the more surprising a message is, the more information it carries).

- The concepts and units by which we endeavor to quantify information and information flow (for example, words, bits, and bits per second).

- Errors; and redundancies and their use in reducing errors (for example, by repeating a message).

- The way in which information can be elaborated (for example, by computation or pattern recognition), carried (messages from transmitter to recipient), and stored (for example, in data banks).

- The physical means of conveying and storing information and the limits imposed by nature (how much can we convey? how fast?); and energy and materials requirements (for example, the electric energy needed to convey a telephone message).

- Examples of information processes in a social system (for example, learning), in a biological system (for example, in the genes, the nervous system, or the brain), and in a human-engineered system (for example, in computers, writing systems, and radar).

- Strategies for acquiring and using information (for example, getting the most information from a deep-space probe with a low-power transmitter—or even the very simple problem of weighing an unknown object using a minimum number of steps, given a set of known weights); and energy savings achieved through information (for example, avoiding wasted motion, be it in factory work, restaurant operations, or a variety of other activities that ultimately—through their efficiency—determine the economic competitiveness and wise utilization of resources, human and otherwise, of a society).

- Information paucity and information overload (an overload is a function of time—that is, of the speed with which information is processed).

The Concept of Systems

The following topics could be included under the concept of system:

- The definition of system (from the broadest definition as a group of entities working together or influencing each other to much more specific ones, such as those involving explicit and clearly characterized interactions or feedback loops).

- How to recognize and construe systems, both abstract and concrete, and natural and human-made (for example, a planetary system, an ecological system, a school, a television network, a factory that makes television sets, a pen, a car, a corporation, or a state); and system hierarchies and system components.

- Systems in static equilibrium versus systems in dynamic equilibrium (for example, a house versus a moving airplane or bicycle).

- The role of feedback and feedforward (for example, the thermostat in a room, or the eye/brain system for approximating the height of a stairway we are climbing); self-adaptive systems

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systems adapting their characteristics and performance to changes in the environment) and their possible degeneration to autonomous systems (systems not responding to the environment); and how a purposeful, self-adaptive system must possess a model of its environment (the importance of knowledge).

- Changes in system properties with size—a topic that can lead to a discussion of how individuality is born out of complexity (we are all made of the same basic atomic building blocks, yet we are all different).

- How to recognize system failures, component failures, component mismatches, and failures at the interfaces between systems; and the problem of complexity at interfaces (for example, how to match the high speed of airplanes with the relatively slow reactions of pilots).

OTHER UNIFYING CONCEPTS

A number of other general concepts are also important to an understanding of a broad range of phenomena and processes in the physical and information sciences and in engineering, and they often cut across the key unifying concepts we have just suggested. For example:

- *The concept of equilibrium* is involved in the movement of a seesaw, in the stability of a structure, and in the reaction rates of chemical processes, including the concept of buffer as a substance that maintains chemical equilibrium.

- *The concept of time rate* describes the flow of water, materials, energy, or information, such as the flow of a liquid in a pipe, the daily output of a factory, the cooling of a body, the progress of a chemical transformation, the transmission capacity of a telephone line, or the climbing performance of an airplane.

- *The concept of conservation* expresses fundamentally the idea that some things are always conserved, such as momentum, energy, and parity—and specifically that matter and energy are indestructible and can only be transformed (from one form to another and into each other), so that the energy and matter within a system (for example, a house furnace or a human digestive tract) can be tracked and budgeted.

- *The concept of efficiency* defines the ratio of useful energy obtained from a machine to the energy supplied to the machine. The term "efficiency" has come to be used by society at large to describe, in a generalized way, input/output relationships in all sorts of physical, biological, social, engineering, and information-processing contexts.

- *The concept of uncertainty* stems from our inability to measure perfectly or calculate completely all the elements in a system—and hence the need to resort to probabilities. The concept has a very precise formulation in the case of a microscopic physical system (Heisenberg uncertainty principle).

- *The concept of risk*, similarly, is of a probabilistic nature. It involves the probability of an unfavorable natural event, such as a flood or an earthquake, or the probability of failure of one of our human-made devices or processes, such as a satellite, a nuclear reactor, or open-heart surgery.

- *The concept of cost-effectiveness*, although of an economic nature, is important to engineering. For example, consider the cost required to build an artifact, such as an airplane or a pollution-control device that will perform with a certain effectiveness (for instance, an airplane that will fly a given distance at a given speed or a device that will remove a certain type and amount of pollutant). It is important to keep in mind, however, that cost is not the primary or only measure of the value of an engineering project, since potential benefit must have other dimensions as well. How could one assess in dollars, for instance, the effectiveness of a pyramid or the pleasure derived from watching a concert on television? Beyond engineering, the concept of cost-effectiveness has come to be used in the sciences (for example, how much does it cost to launch a space probe, and how much information do we derive from it?) and in other human activities.

The concept of benefit analysis, which is related to that of cost-effectiveness, is another important general concept. It deals with the assessment of the benefits brought about by a given human action or artifact. For instance, in health care, how much benefit do we derive from screening a population for lung cancer once a year—and at what risk? Again, there are inherent problems in translating an intangible, such as the value of health or human life or ecological preservation, into a tangible, such as dollars. Potentially cost-effective airplanes, for example, may never be built owing to non-cost-related considerations, such as environmental damage; conversely, it may be beneficial to engage in engineering projects—such as providing facilities for people with disabilities—that may not be cost-effective in some sense.

To reiterate, general concepts such as those summarized above have acquired significance beyond the physical and information sciences and engineering, so that we talk of political or ecological equilibrium, of rate of progress or inflation, of oscillating or drastically unstable financial markets, or of conservation of natural resources. Thus, these concepts can help interconnect the physical and information sciences and engineering, other sciences, and (more generally) other aspects of society. For instance, one could discuss how the relative abundance or scarcity of mineral resources or the invention of increasingly effective ways of utilizing energy have influenced societies (for example, coal and the Industrial Revolution; oil and the automobile; and the OPEC countries). One could also discuss the historical trend in civilization from early societies dependent on materials and energy sources (primarily human and animal, plus the sun and wind) to the energy-rich societies of the Industrial Revolution, to today's societies in which information-related activities become the predominant occupation of the population (postindustrial service economies).

SECTION 6

KEY SPECIFIC CONCEPTS

The unifying concepts outlined above provide common threads that should serve as a useful guide to the spectrum of disciplines encompassed under the label of the physical and information sciences and engineering. High school graduates cannot be expected to be knowledgeable in all aspects of this spectrum. However, there are some key concepts specific to each discipline or group of disciplines—that is, to *physics and chemistry;* the *earth, planetary and astronomical sciences,* the *information sciences;* and *engineering*—that all high school students should have the opportunity to explore and understand, at least to some degree.

These key concepts are discussed in this section. For many of these concepts, the discussion includes a list of "relevant items." Such lists are not intended to be lists of topics that will necessarily be included in a curriculum; rather, they are presented simply as items that can be addressed to clarify or amplify a specific key concept. It is up to the teacher or student to decide how deeply to explore them. We stress that the key specific concepts provide a simple but solid disciplinary foundation that complements the unifying concepts, and they can be expanded as needed.

We leave open, furthermore, the question as to whether traditional disciplinary divisions—such as the one between physics and chemistry that we have eliminated here—should be preserved in school curricula in the future. Should the science disciplines be merged by focusing on unifying concepts (such as the ones identified in Section 5) and on the integrative approach to teaching (discussed in Section 7)? The answer will depend largely on each teacher's experience and success in the classroom. However, even if the disciplines are conceptually or pedagogically merged or integrated, there will continue to be a need for specific concepts and laboratories in physics, chemistry, computation, and so forth for specific sets of phenomena.

Given the central importance of mathematics for an understanding of the physical and information sciences and engineering, we strongly reiterate the need to teach it in an integrated fashion with these subjects. Most specific concepts in physics, the other physical sciences, and engineering can be approached in two mutually reinforcing ways—through experimentation and through mathematics. The integrative approach shows the clarifying and enhancing value of a mathematical description of a phenomenon.

To develop such a description, the student needs enough familiarity and experience with derivatives and integrals to be able to formulate laws of science more generally as differential equations. As an example, the normal distribution, or Maxwellian, can be understood simply through the shape of its curve. More precise understanding calls for knowledge of the exponential function, which is best defined as a solution of the differential equation $y' = y$. Another example is Newton's second law of motion. This is most easily formulated in mathematical terms as the ordinary differential equation $m\, x'' = f$. Other fundamental conservation laws of physics and engineering have similar mathematical representations that are easier to learn than to circumvent.

Although these calculus concepts are not now within the realm of the typical high school graduate, we feel that they can be approached and understood, if only through difference equations or finite sums and averages. Teachers should not shy away from offering, albeit in simplified form, an understanding of some of the key equations used to describe physical reality. The sooner the student acquires an understanding of how the elements of physical reality can be powerfully described through the use of these equations, the sooner a great deal of science will become demythologized and the student will feel more comfortable with science.

PHYSICS AND CHEMISTRY

Physicists try to understand the world in terms of as few basic concepts as possible—concepts that not so much underlie as *lie within* all the other sciences. They focus on the nature and behavior of very simple systems such as atoms, and also on complex systems, insofar as the behavior of such systems is simple (in airless space, for instance, a mouse and a moon will fall at the same rate as a molecule).

Chemists endeavor to understand how the world works in terms of the behavior of the atoms and molecules of substances (reactants) that interact with each other to produce materials whose properties are different from those of the reactants.

We believe that experiments are essential to the development of an understanding of physics and chemistry concepts. School curricula should emphasize simple experiments that make the point but are not costly. Very simple "kitchen" experiments could even be started at the preschool level.

Key Concepts

- *All Physical and Chemical Phenomena Are Governed by a Few Basic Interactions*

Relevant Items[3]: The basic laws of gravity, electricity, and magnetism; the electromagnet; the gross characteristics of the strong and weak nuclear interactions; and the concept of a field to describe a force—for example, between two electrons—as the (electric) field of one or the other.

Comments: One central pursuit of modern physicists is to discover the unity of nature, as demonstrated in the identity of seemingly different fundamental interactions. In addition to being able to describe the main characteristics of these interactions as we know them today, students should be aware of the deep cultural and philosophical implications of this pursuit, as well as of its incomplete, ongoing nature.

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[3] We emphasize the facultative nature of the relevant items as being guides for further expanding, when desired, some understanding of a key concept and its applications—but most emphatically not as obligatory topics to be taught or learned.

- ***The Quantum Principle: On a Microscopic-Length Scale, Many Physical Quantities—Such as Electric Charge, Mass, and Energy—Are Found in Tiny Fixed Units Called Quanta; Atoms Gain and Lose Energy in Fixed Quantum Units***

Relevant Items: All matter is built up of particles. An atom consists of a tiny but relatively massive nucleus of protons and neutrons surrounded by a cloud of electrons equal in number to the protons. The stable existence of atoms (that is, chemical matter) requires quantized energy states of atoms, analogous to the separate resonant vibration frequencies of a violin string. Photons are quanta of electromagnetic energy.

Comments: Changes in the energy of a quantum system such as an atom or a nucleus are accompanied by absorption or emission of the precise energy difference in a quantum of radiation (photon) or as a change in kinetic energy—as occurs in nuclear fission or nuclear fusion. This concept, we believe, is easier for today's children to grasp than it was for adults when it first emerged in the 1920s. The quantum concepts apply to all materials, including biological materials. For instance, the eye detects photons; photons are also absorbed by plants in photosynthesis.

- ***The Behavior of Simple Static and Moving Systems Can Be Explained Using the Laws First Laid Out by Isaac Newton***

Relevant Items: Velocity; acceleration; rotation; force, work, power; friction; vector addition of forces; impulse, momentum, and angular momentum; and inertia.

Comments: Static and moving systems are a ubiquitous part of our everyday reality. Such a system may consist of a pulley, a house, a bridge, a car going around a corner, a bullet shot from a rifle, a boat, or an airplane. Students derive immediate practical benefits from learning to understand what happens—in terms of motion or internal forces—in a variety of such systems.

- ***Intuitive Ideas of Space, Time, Energy, and Mass Fail at Great Distances and When Speeds Approach the Speed of Light***

Relevant Items: Light from the sun takes 8.3 minutes to reach the earth. If a person in a spaceship could leave the Big Ben tower clock at 12 noon at the speed of light, he would never see its hands move, since the light from 12:01 would never reach him. Albert Einstein first postulated that moving clocks in general appear to run more slowly than clocks located with the observer (still a puzzle to the lay person). The speed of light, 186,000 miles per second, cannot be exceeded, and it has the same value when measured by any moving observer. The energy needed to accelerate objects to almost this speed vastly exceeds that calculated conventionally. Space travel at close to this speed, therefore, is not possible because of the energy cost.

Comments: Careful reasoning about space, time, and the fixed speed of light led Einstein to conclude that energy and mass are equivalent, according to the rule $E = mc^2$, where E is the energy, m is the mass, and c is the speed of light. This is a working equation in nuclear reactions and nuclear power, where the kinetic and radiation energy released is calculated by taking m as the change in the rest mass of the nuclear fuel after reactions have occurred. The same rule can even be applied to chemical reactions (for example, in an explosion of TNT), but the change in mass is much smaller. An example of a process of direct and complete conversion of rest mass to energy occurs when an electron and a positron (positive electron) annihilate.

- ***Electromagnetic Radiation, of Which Light Is an Example, Occurs in a Very Large Range of Wavelengths; Such Radiation Is Emitted and Absorbed as Particles or Bundles of Energy***

Relevant Items: Lenses and mirrors; reflection and refraction; interference; diffraction; polarization; characteristics of the emission, absorption, and propagation of electromagnetic radiation from radio and television signals to x rays; color and the human visual system; photoelectric effect; and photons and the idea of the quantum.

Comments: Many of these phenomena can be demonstrated by means of relatively simple examples. Since humans assimilate a considerable amount of information visually, the explanation of human vision and its limits provides a particularly immediate link between physical ideas and the world around the student, helping to bring science closer to home. Students should be able to explain a good sampling of common optical phenomena, such as reflections in a shiny spoon, infrared photographs, and rainbows. Understanding the relationship between the dormant color of a glowing body and its temperature leads to the idea of the quantum.

- ***Electrical Phenomena Can Be Understood in Terms of the Behavior of Electric Charge***

Relevant Items: Electrons flowing and carrying information and energy; static electricity; lightning; current, voltage, and resistance; capacitance; batteries; electrons flowing from a hot filament to a target; cathode-ray tubes; and overview of solid-state electronics—for example, the transistor.

Comments: The ability to understand these concepts—developed through demonstration (often relying on very simple circuits)—is of great practical value for citizens confronted with all sorts of electrical and electronic devices. Also of value to them are knowledge of basic computer architecture (including the typical components and how they are connected) and an understanding of the hazards of electric currents and how to avoid such hazards.

- ***For Many Purposes, Matter Can Be Viewed as Being Composed of Atoms and Molecules That Have Well-Defined Sizes, Shapes, Structures, Compositions, and Energy Contents***

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Relevant Items: The historical development of chemistry and of the atomic theory, what causes the atoms of the various elements to be different (subatomic structure), the electronic nature of chemical bonding (why some atoms stick together eadily and others do not), valence, types of

(covalent, ionic), why bonds have spatial direction, molecular isomerism (for example, how many molecules have the empirical formula C_6H_{14} and what are their structures?), atomic and molecular dimensions (compared to dimensions with which students are familiar), and how molecular compositions and structures are determined (use of modern analytical instrumentation, such as infrared and ultraviolet spectrometers).

Comments: If students think in atomic and molecular terms, they will be able to gain the insight that chemistry provides into the behavior of physical systems. Systems of actual or potential interest to the average citizen can range in size and complexity from the subatomic to the universe as a whole.

- ***Atomic Nuclei Undergo Changes***

Relevant Items: Radioactivity (types, sources, methods of detection, isotopes, half-lives, and biological impacts), nuclear energy (fission and fusion, methods of control, and conservation of energy and matter), the transmutation of elements, and the synthesis of new elements.

Comments: These changes are related to the basic structure of matter. It is essential that citizens be familiar with some manifestations and effects of these changes, such as x rays, luminous watches, nuclear magnetic resonance, nuclear power, and solar radiation.

- ***Energy and Matter Manifest Themselves in Many Ways, Are Transported and Transformed, and Are Conserved***

Relevant Items: Forms of energy—mechanical, sensible and latent heat, electromagnetic, chemical, electrical, nuclear; the conservation of matter and energy; the first and second laws of thermodynamics; energy efficiency; the generation, conversion, storage, and transport of energy, especially heat flow.

Comments: The pendulum provides a very simple demonstration of energy conversion (from kinetic to potential and vice versa). Much of the sound reasoning in the domain of the physical sciences that will be helpful in everyday life comes from a clear understanding of the budgeting and conversion of matter and energy. Questions such as "Tell what is happening with matter and energy when you carry a pail of water upstairs and throw it out the window" can guide a student to this type of thinking. The topic is particularly important as a basis not only for physics and chemistry but also for other sciences such as biology, and for engineering.

- ***The Behavior of Matter Under Various Common Circumstances Is Dependent On Its Physical State (Solid, Liquid, or Gaseous)***

Relevant Items: Brownian motion (for example, how do molecules move around in air and in water?); the molecular basis of temperature and pressure (for example, when a rubber band is stretched, why does its temperature change?); phase transformation; simple hydrostatics; fluid pressure laws; steady flow versus turbulence; oscillations, water waves, and sound waves; earthquakes; and resonance.

Comments: Examples of how the behavior of matter is dependent on its physical state abound in everyday life. The ability to explain that behavior in broad terms helps us, for instance, to better understand ourselves as fluid organisms (blood, circulation, respiration, cell fluidity, synaptic transmission of information, hormones, etc.) and our environment (air, water, and solids). Very simple experiments involving fluid pressure can be performed using a bicycle pump or using a liquid-filled plastic tube; phase-change experiments can be done using dry ice or a kitchen stove; and turbulence experiments can be done using a smoke source. Students' mathematical understanding should advance to the point where parallels can be drawn among some of these phenomena, as well as with phenomena in systems outside physics (for example, oscillations in liquids and solids, and liquid analogies to traffic flow).

• *Matter Undergoes Chemical Transformations (Reactions) Whose Nature and Occurrence Are Dependent Upon the Intrinsic Features of Atoms and Molecules and Upon the Surrounding Environment*

Relevant Items: The difference between physical and chemical changes, strengths of chemical bonds, attractive and repulsive chemical forces, periodicity of the elements (with respect to both structure and properties), elementary thermodynamics (concepts of entropy and free energy), conservation of mass in chemical and physical changes, and why chemical phenomena are reproducible.

Comments: The conversion of matter into other forms is observed daily by all people, but the difference between physical and chemical changes is not commonly perceived. To comprehend how the world works, citizens should understand that phase changes (physical changes, such as steam to liquid, and water to ice) are reversible and do not bring about fundamental alterations in the properties of matter; on the other hand, chemical transformations (for example, combustion) frequently are irreversible and lead to changes in matter at an extremely basic level.

• *Chemical Transformations of Atoms and Molecules Produce Materials Whose Properties Differ From Those of the Reactants*

Relevant Items: Acid/base reactions, oxidation and reduction (combustion, rusting, electrochemistry, and batteries), polymerization, stoichiometry (the laws of chemical combination), the synthesis of celluloid and new materials (drugs; plastics such as polyethylene and polyvinyl chloride; fibers such as rayon and nylon; electronic materials; etc.), the effects of chemical change on local and global environments (the greenhouse effect, acid rain, and depletion of the ozone layer), chemical changes in living organisms, biopolymers (polypeptides and polysaccharides), chemical raw materials (aluminum, sulfur, and petrochemicals—their uses and their extraction from natural sources), how macroscopic properties depend on atomic and molecular properties (why are metals shiny and why do organic dyestuffs have various colors?), and energy storage by molecular systems (chemical techniques for storing solar energy).

Comments: Chemical changes brought about by humans have produced an enormous number of new and useful synthetic materials. Yet, the industrial production of these materials has led to environmental problems. Any unknown chemical (and most chemicals are unknown to the public) should be approached with caution. Students could learn to perform their own risk/benefit assessment of these matters in an enlightened fashion. Like synthetic chemical changes, natural chemical transformations (defined as those not involving human intervention) may be either beneficial (for example, life processes) or deleterious (for example, the rusting of iron).

- ***The Rates of Chemical Reactions Are Determined by the Atomic and Molecular Properties of the Reactants and by the Reaction Environment***

Relevant Items: How rates are affected by bond strengths and molecular geometry (simple examples from organic chemistry), how bonds cleave, reactive intermediates (ions, free radicals, and other metastable species), catalysis (catalytic cracking in the petroleum industry), chain reactions (for example, hydrocarbon autoxidation), the effects of reaction variables (media, temperature, and pressure) on the reaction rates, the concepts of activation energy and the activated complex, photochemistry, the nature of chemical equilibrium behavior, and a reiteration of the general relevance of the equilibrium concept to various types of systems (for example, a buffered solution, a seesaw, a lever, a biological ecosystem, or a city).

Comments on the Teaching of Chemistry

As stressed above in Section 1, the context in which science is taught is as crucial to learning as the curriculum itself. This is particularly important in the case of chemistry. In the past, science teaching in the schools has tended to focus on chemistry per se, rather than on its pervasive influence upon many types of phenomena that can be observed by the physical senses. As a result, students have usually been unable to think about such phenomena in molecular terms; that is, how the properties of individual molecules contribute to the behavior of large and small systems. More specifically, most students have not been guided to appreciate the real-world relevance of the concepts of molecular size, shape, structure, and reactivity (for example: How big is an atom? How many atoms and molecules are contained in macroscopic objects? How do the size and geometry of molecules influence their efficacy as drugs? Why is rubber an elastic material? Why do perfumes have pleasant odors? How do molecular composition and reactivity lead to the problem of acid rain?).

The general public usually thinks of chemicals as being artificial substances that have societal benefits in some cases but are responsible for unpleasant smells, major health problems such as cancer and chronic respiratory diseases, and the destruction of the environment. This stereotyped image of chemistry and chemicals needs to be corrected by teaching (1) the pervasiveness of chemicals (all matter above the subatomic level is composed of chemicals), (2) the need for caution in producing and using chemical materials, (3) the actual and potential contributions of chemistry to the solution of existing social and environmental problems (for example, chemical contraceptives, atmospheric chemical analysis, and laboratory reactivity studies pertaining to the ozone-layer problem), and (4) the other societal benefits of chemistry.

EARTH, PLANETARY, AND ASTRONOMICAL SCIENCES

The earth, planetary, and astronomical sciences differ substantially from such sciences as physics, chemistry, and biology in that experimentation is not always possible. Continents, and the forces that drive them to collide, can hardly be created in the laboratory. Nor can the evolution of a star be duplicated on earth. Instead, many earth and planetary scientists and astronomers must make use of only what they can see and record, and must resort to generalizations, models, and analogies. Nature itself becomes the laboratory, and we must seek out the experiments nature is running at present, observe them and generalize from them, and then go to new places to observe nature's new experiments.

The earth and related sciences often rely on the concept of process, by which large-scale objects interact in predictable ways. Thus, we speak of the process of glaciation, in which ice moves from mountain peaks and landscapes are carved. Although we could try to reduce this process to the physics of atoms of solid water moving under the influence of gravity, it is often more useful to consider the glacier itself as an agent of erosion that produces distinctive landforms. Understanding the process, therefore, requires a different level of abstraction than does the mastering a law of physics or chemistry. But a sound knowledge of the underlying physics and chemistry is usually essential for a thorough knowledge of the process. In fact, many basic concepts in physics, chemistry, biology, and even mathematics can be taught within the context of the processes studied in the earth, planetary, and astronomical sciences.

Study of the atmosphere and oceans is essential to an understanding the earth's surface. These fluid layers are the global transportation networks of heat, and they create climate and weather and serve as buffers to maintain environmental equilibrium (homeostasis). They are responsible for the origin and ultimate preservation of life on our planet. Thus, oceanography and meteorology, the sciences that study these layers, although relatively new, are of great importance in secondary and elementary school curricula. Therefore, we have included several key concepts from these fields to help teachers and students. We have chosen to arrange these concepts to proceed from the universe to our galaxy to the solar system to the earth. Obviously, other sequences may be preferred (for example, starting from the earth).

Key Concepts

- *Our Universe Has an Enormous Number of Galaxies*

Until modern times, humankind had little but myth and speculation in the way of information about things beyond the earth.

However, we now realize that our universe has an enormous number of galaxies, each with an enormous number of stars of various kinds, many of them similar to our sun. Currently, we believe that this universe originated 15 or so billion years ago as an extraordinarily hot, dense mass of elementary particles—a mass that is still expanding and cooling. From the gases, stars coalesce, and within their furnaces the chemical elements are built up. Some stars explode, and from the resulting clouds new stars and also planets coalesce.

Relevant Items: The history of astronomy; instrumentation to study things beyond reach; energy and mass in the universe; hints about cosmology and its relation to particle physics; galaxies; the varieties of stars and a glimpse of their evolution; the "ecology" of galaxies; nuclear reactions; the origin and relative abundance of the elements; and speculations about the formation of planetary systems.

Comments: This topic is worth studying not only for its direct practical value but also because it answers deeper needs, such as to know what can be known about ultimate origins and destinations and about the place of humanity in the cosmos. The topic therefore calls for particular efforts to relate scientific ideas to our highest ideals, as expressed in religion, literature, and the arts. Along the way, space science serves as a useful way to introduce or review some features of physics. It is also a rich source of understanding for the history of the scientific method, and especially for how we study things far beyond our immediate grasp.

- *The Sun Is One of the Many Stars Within the Milky Way Galaxy; the Earth Is One of the Planets of the Sun*

Our sun is one of many stars within the Milky Way galaxy, but to reach any other star—even the one closest to the sun—at current rocket speeds would take tens of thousands of years. The sun's energy comes from nuclear reactions deep within it; this has been going on for several billion years and will go on for several billion more. Most of the sun's energy flows out as light, but great surface explosions also affect the space around the sun. A number of planets and moons (and rocks, dust, and ice) orbit within this space. They have strikingly diverse characteristics. Only one of these bodies can readily support human life, and it does; that is the earth.

Relevant Items: The nuclear source of solar energy and its regulation; comparison with controlled thermonuclear fusion in the laboratory; the lifetime of the sun; solar weather and the space environment; meteorites and comets; other planets, especially in comparison with the chemical composition, geology, climate, etc. of the earth.

Comments: Some of the subjects involved also have very important if indirect practical value—for example, the calendar and its impact on agriculture, navigation (and at times its impact on mathematics, chronometry, and instrumentation), navigation satellites, space probes (and their impact on miniaturization), and the understanding that life on the earth depends on a delicate balance between enormous forces.

The College Board's
Advanced Placement (AP™)
United States History

Guide for Advanced Placement United States History Test Coverage

1. Discovery and Settlement of the New World, 1492–1650
    - A. Europe in the sixteenth century
    - B. Spanish, English, and French exploration
    - C. First English settlements
        - 1. Jamestown
        - 2. Plymouth
    - D. Spanish and French settlements and long-term influence
    - E. Native Americans (Indians)
2. America and the British Empire, 1650–1754
    - A. Chesapeake country
    - B. Growth of New England
    - C. Restoration colonies
    - D. Mercantilism; the Dominion of New England
    - E. Origins of slavery
3. Colonial Society in the Mid-Eighteenth Century
    - A. Social structure
        - 1. Family
        - 2. Farm and town life; the economy
    - B. Culture
        - 1. Great Awakening
        - 2. The American mind
        - 3. "Folkways"
    - C. New immigrants
4. Road to Revolution, 1754–1775
    - A. Anglo-French rivalries and Seven Years' War
    - B. Imperial reorganization of 1763
        - 1. Stamp Act
        - 2. Declaratory Act
        - 3. Townshend Acts
        - 4. Boston Tea Party
    - C. Philosophy of the American Revolution

5. The American Revolution. 1775–1783
   A. Continental Congress
   B. Declaration of Independence
   C. The war
      1. French alliance
      2. War and society; Loyalists
      3. War economy
   D. Articles of Confederation
   E. Peace of Paris
   F. Creating state governments
      1. Political organization
      2. Social reform: women, slavery

6. Constitution and New Republic, 1776–1800
   A. Philadelphia Convention: drafting the Constitution
   B. Federalists versus Anti-Federalists
   C. Bill of Rights
   D. Washington's presidency
      1. Hamilton's financial program
      2. Foreign and domestic difficulties
      3. Beginnings of political parties
   E. John Adams' presidency
      1. Alien and Sedition Acts
      2. XYZ affair
      3. Election of 1800

7. The Age of Jefferson, 1800–1816
   A. Jefferson's presidency
      1. Louisiana Purchase
      2. Burr conspiracy
      3. The Supreme Court under John Marshall
      4. Neutral rights, impressment, embargo
   B. Madison
   C. War of 1812
      1. Causes
      2. Invasion of Canada
      3. Hartford Convention
      4. Conduct of the war
      5. Treaty of Ghent
      6. New Orleans

8. Nationalism and Economic Expansion
  A. James Monroe; Era of Good Feelings
  B. Panic of 1819
  C. Settlement of the West
  D. Missouri Compromise
  E. Foreign affairs: Canada, Florida, the Monroe Doctrine
  F. Election of 1824: End of Virginia dynasty
  G. Economic revolution
    1. Early railroads and canals
    2. Expansion of business
      a. Beginnings of factory system
      b. Early labor movement; women
      c. Social mobility; extremes of wealth
    3. The cotton revolution in the South
    4. Commercial agriculture

9. Sectionalism
  A. The South
    1. Cotton Kingdom
    2. Southern trade and industry
    3. Southern society and culture
      a. Gradations of white society
      b. Nature of slavery: "peculiar institution"
      c. The mind of the South
  B. The North
    1. Northeast industry
      a. Labor
      b. Immigration
      c. Urban slums
    2. Northwest agriculture
  C. Westward expansion
    1. Advance of agricultural frontier
    2. Significance of the frontier
    3. Life on the frontier; squatters
    4. Removal of the Native Americans (Indians)

10. Age of Jackson. 1828–1848
    - A. Democracy and the "common man"
        - 1. Expansion of suffrage
        - 2. Rotation in office
    - B. Second party system
        - 1. Democratic Party
        - 2. Whig Party
    - C. Internal improvements and states' rights: the Maysville Road veto
    - D. The Nullification Crisis
        - 1. Tariff issue
        - 2. The Union: Calhoun and Jackson
    - E. The Bank War: Jackson and Biddle
    - F. Martin Van Buren
        - 1. Independent treasury system
        - 2. Panic of 1837

11. Territorial Expansion and Sectional Crisis
    - A. Manifest Destiny and mission
    - B. Texas annexation, the Oregon boundary, and California
    - C. James K. Polk and the Mexican War: slavery and the Wilmot Proviso
    - D. Later expansionist efforts

12. Creating an American Culture
    - A. Cultural nationalism
    - B. Educational reform/professionalism
    - C. Religion; revivalism
    - D. Utopian experiments: Mormons, Oneida Community
    - E. Transcendentalists
    - F. National literature, art, architecture
    - G. Reform crusades
        - 1. Feminism; roles of women in the nineteenth century
        - 2. Abolitionism
        - 3. Temperance
        - 4. Criminals and the insane

13. The 1850s: Decade of Crisis
    A. Compromise of 1850
    B. Fugitive Slave Act and *Uncle Tom's Cabin*
    C. Kansas-Nebraska Act and realignment of parties
        1. Demise of the Whig Party
        2. Emergence of the Republican Party
    D. Dred Scott decision and Lecompton crisis
    E. Lincoln-Douglas debates, 1858
    F. John Brown's raid
    G. The election of 1860: Abraham Lincoln
    H. The secession crisis

14. Civil War
    A. The Union
        1. Mobilization and finance
        2. Civil liberties
        3. Election of 1864
    B. The South
        1. Confederate constitution
        2. Mobilization and finance
        3. States' rights and the Confederacy
    C. Foreign affairs and diplomacy
    D. Military strategy, campaigns, and battles
    E. The abolition of slavery
        1. Confiscation Acts
        2. Emancipation Proclamation
        3. Freedmen's Bureau
        4. Thirteenth Amendment
    F. Effects of war on society
        1. Inflation and public debt
        2. Role of women
        3. Devastation of the South
        4. Changing labor patterns

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15. Reconstruction to 1877
    - A. Presidential plans: Lincoln and Johnson
    - B. Radical (congressional) plans
        - 1. Civil rights and the Fourteenth Amendment
        - 2. Military reconstruction
        - 3. Impeachment of Johnson
        - 4. Black suffrage: the Fifteenth Amendment
    - C. Southern state governments: problems, achievements, weaknesses
    - D. Compromise of 1877 and the end of Reconstruction

16. New South and the Last West
    - A. Politics in the New South
        - 1. The Redeemers
        - 2. White and black Americans in the New South
        - 3. Subordination of freedmen: Jim Crow
    - B. Southern economy; colonial status of the South
        - 1. Sharecropping
        - 2. Industrial stirrings
    - C. Cattle kingdom
        - 1. Open-range ranching
        - 2. Day of the cowboy
    - D. Building the Western railroad
    - E. Subordination of the Native American (Indian): dispersal of tribes
    - F. Farming the plains; problems in agriculture
    - G. Mining bonanza

17. Industrialization and Corporate Consolidation
    A. Industrial growth: railroads, iron, coal, electricity, steel, oil, banks
    B. Laissez-faire conservatism
        1. Gospel of Wealth
        2. Myth of self-made man
        3. Social Darwinism; survival of the fittest
        4. Social critics and dissenters
    C. Effects of technological development on worker/workplace
    D. Union movement
        1. Knights of Labor and American Federation of Labor
        2. Haymarket, Homestead, and Pullman

18. Urban Society
    A. Lure of the city
    B. Immigration
    C. City problems
        1. Slums
        2. Machine politics
    D. Awakening conscience; reforms
        1. Social legislation
        2. Settlement houses: Jane Addams and Lillian Wald
        3. Structural reforms in government

19. Intellectual and Cultural Movements
    A. Education
        1. Colleges and universities
        2. Scientific advances
    B. Professionalism and the social sciences
    C. Realism in literature and art
    D. Mass culture
        1. Use of leisure
        2. Publishing and journalism

20. National Politics. 1877–1896: The Gilded Age
    - A. A conservative presidency
    - B. Issues
        - 1. Tariff controversy
        - 2. Railroad regulation
        - 3. Trusts
    - C. Agrarian discontent
    - D. Crisis of 1890s
        - 1. Populism
        - 2. Silver question
        - 3. Election of 1896: McKinley versus Bryan

21. Foreign Policy, 1865–1914
    - A. Seward and purchase of Alaska
    - B. The new imperialism
        - 1. Blaine and Latin America
        - 2. International Darwinism: missionaries, politicians, and naval expansionists
        - 3. Spanish-American War
            - a. Cuban independence
            - b. Debate on Philippines
    - C. The Far East: John Hay and the Open Door
    - D. Theodore Roosevelt
        - 1. The Panama Canal
        - 2. Roosevelt Corollary
        - 3. Far East
    - E. Taft and Dollar Diplomacy
    - F. Wilson and Moral Diplomacy

22. Progressive Era
    A. Origins of Progressivism
        1. Progressive attitudes and motives
        2. Muckrakers
        3. Social Gospel
    B. Municipal, state, and national reforms
        1. Political: suffrage
        2. Social and economic: regulation
    C. Socialism: alternatives
    D. Black America
        1. Washington, Du Bois, and Garvey
        2. Urban migration
        3. Civil rights organizations
    E. Women's role: family, work, education, unionization, and suffrage
    F. Roosevelt's Square Deal
        1. Managing the trusts
        2. Conservation
    G. Taft
        1. Pinchot-Ballinger controversy
        2. Payne-Aldrich Tariff
    H. Wilson's New Freedom
        1. Tariffs
        2. Banking reform
        3. Anti-Trust Act of 1914

23. The First World War
    - A. Problems of neutrality
        - 1. Submarines
        - 2. Economic ties
        - 3. Psychological and ethnic ties
    - B. Preparedness and pacifism
    - C. Mobilization
        - 1. Fighting the war
        - 2. Financing the war
        - 3. War boards
        - 4. Propaganda, public opinion, civil liberties
    - D. Wilson's Fourteen Points
        - 1. Treaty of Versailles
        - 2. Ratification fight
    - E. Postwar demobilization
        - 1. Red scare
        - 2. Labor strife

24. New Era: The 1920s
    - A. Republican governments
        - 1. Business creed
        - 2. Harding scandals
    - B. Economic development
        - 1. Prosperity and wealth
        - 2. Farm and labor problems
    - C. New culture
        - 1. Consumerism: automobile, radio, movies
        - 2. Women, the family
        - 3. Modern religion
        - 4. Literature of alienation
        - 5. Jazz age
        - 6. Harlem Renaissance
    - D. Conflict of cultures
        - 1. Prohibition, bootlegging
        - 2. Nativism
        - 3. Ku Klux Klan
        - 4. Religious fundamentalism versus modernists
    - E. Myth of isolation
        - 1. Replacing the League of Nations
        - 2. Business and diplomacy

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25. Depression, 1929–1933
    A. Wall Street crash
    B. Depression economy
    C. Moods of despair
        1. Agrarian unrest
        2. Bonus march
    D. Hoover-Stimson diplomacy; Japan

26. New Deal
    A. Franklin D. Roosevelt
        1. Background, ideas
        2. Philosophy of New Deal
    B. 100 Days; "alphabet agencies"
    C. Second New Deal
    D. Critics, left and right
    E. Rise of CIO; labor strikes
    F. Supreme Court fight
    G. Recession of 1938
    H. American people in the Depression
        1. Social values, women, ethnic groups
        2. Indian Reorganization Act
        3. Mexican-American deportation
        4. The racial issue

27. Diplomacy in the 1930s
    A. Good Neighbor Policy: Montevideo, Buenos Aires
    B. London Economic Conference
    C. Disarmament
    D. Isolationism: neutrality legislation
    E. Aggressors: Japan, Italy, and Germany
    F. Appeasement
    G. Rearmament; Blitzkrieg; Lend-Lease
    H. Atlantic Charter
    I. Pearl Harbor

28. The Second World War
    - A. Organizing for war
        - 1. Mobilizing production
        - 2. Propaganda
        - 3. Internment of Japanese-Americans
    - B. The war in Europe, Africa, and the Mediterranean: D Day
    - C. The war in the Pacific: Hiroshima, Nagasaki
    - D. Diplomacy
        - 1. War aims
        - 2. War-time conferences: Teheran, Yalta, Potsdam
    - E. Postwar atmosphere; the United Nations

29. Truman and the Cold War
    - A. Postwar domestic adjustments
    - B. The Taft-Hartley Act
    - C. Civil rights and the election of 1948
    - D. Containment in Europe and the Middle East
        - 1. Truman Doctrine
        - 2. Marshall Plan
        - 3. Berlin crisis
        - 4. NATO
    - E. Revolution in China
    - F. Limited war: Korea, MacArthur

30. Eisenhower and Modern Republicanism
    A. Domestic frustrations: McCarthyism
    B. Civil rights movement
        1. The Warren Court and *Brown v. Board of Education*
        2. Montgomery bus boycott
        3. Greensboro sit-in
    C. John Foster Dulles's foreign policy
        1. Crisis in Southeast Asia
        2. Massive retaliation
        3. Nationalism in Southeast Asia, the Middle East, Latin America
        4. Khrushchev and Berlin
    D. American People: homogenized society
        1. Prosperity: economic consolidation
        2. Consumer culture
        3. Consensus of values
    E. Space race

31. Kennedy's New Frontier; Johnson's Great Society
    A. New domestic programs
        1. Tax cut
        2. War on poverty
        3. Affirmative action
    B. Civil rights and civil liberties
        1. Black Americans: political, cultural, and economic roles
        2. The leadership of Martin Luther King, Jr.
        3. Resurgence of feminism
        4. The New Left and the Counterculture
        5. Emergence of the Republican party in the South
        6. The Supreme Court and the *Miranda* decision
    C. Foreign Policy
        1. Bay of Pigs
        2. Cuban missile crisis
        3. Vietnam quagmire

32. Nixon
    - A. Election of 1968
    - B. Nixon–Kissinger foreign policy
        - 1. Vietnam: escalation and pullout
        - 2. China: restoring relations
        - 3. Soviet Union: detente
    - C. New Federalism
    - D. Supreme Court and *Roe* v. *Wade*
    - E. Watergate crisis and resignation

33. The United States since 1974
    - A. The New Right and the conservative social agenda
    - B. Ford and Rockefeller
    - C. Carter
        - 1. Deregulation
        - 2. Energy and inflation
        - 3. Camp David accords
        - 4. Iranian hostage crisis
    - D. Reagan
        - 1. Tax cuts and budget deficits
        - 2. Defense buildup
        - 3. New disarmament treaties
        - 4. Foreign crises: the Persian Gulf and Central America
    - E. Society
        - 1. Old and new urban problems
        - 2. Asian and Hispanic immigrants
        - 3. Resurgent fundamentalism
        - 4. Black Americans and local, state, and national politics

In addition to exposing students to the historical content listed above, an Advanced Placement course should also train students to analyze and interpret primary sources, including documentary material, maps, statistical tables, and pictorial and graphic evidence of historical events. Students should learn to take notes from both printed materials and lectures or discussions, write essay examinations, and write analytical and research papers. They should be able to express themselves with clarity and precision and know how to cite sources and credit the phrases and ideas of others.

Following are questions of the kind appearing in the multiple-choice section of the examination. As a group, they reflect the proportionate emphases found in the examination in relation to types of history (i.e., political, social, economic, intellectual, and diplomatic) and to chronological periods. The distribution of question difficulties also approximates that on the examination. An answer key to multiple-choice questions can be found on page 75.

Directions: Each of the questions or incomplete statements is followed by five suggested answers or completions. Select the one that is best in each case.

1. *Brown* v. *Board of Education of Topeka* was a Supreme Court decision that
   (A) was a forerunner of the Kansas-Nebraska Act
   (B) established free public colleges in the United States
   (C) declared racially segregated public schools inherently unequal
   (D) established free public elementary and secondary schools in the United States
   (E) provided for federal support of parochial schools

2. The issue of constitutionality figured most prominently in the consideration of which of the following?
   (A) Tariff of 1789
   (B) First Bank of the United States
   (C) Funding of the national debt
   (D) Assumption of state debts
   (E) Excise tax on whisky

3. The presidential election of 1840 is often considered the first "modern" election because
   (A) the slavery issue was first raised in this campaign
   (B) there was a very low turnout of eligible voters
   (C) voting patterns were similar to those later established in the 1890s
   (D) both parties for the first time widely campaigned among all the eligible voters
   (E) a second era of good feeling had just come to a close, marking a new departure in politics

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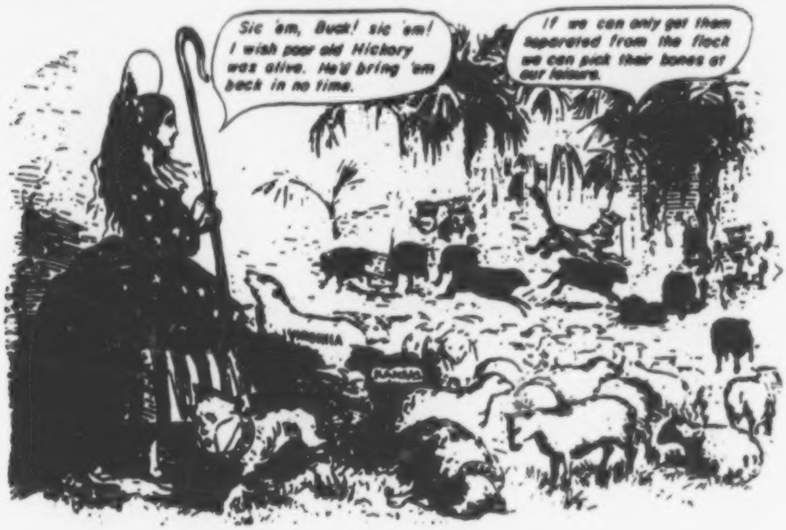
4. Which of the following sources would be useful in studying social mobility and stratification?
   - I. Manuscript census returns
   - II. Election returns
   - III. The President's executive orders
   - IV. City directories
   - V. Tax records

   (A) I and IV only
   (B) I, IV, and V only
   (C) II, III, and V only
   (D) II, III, IV, and V only
   (E) I, II, III, IV, and V

5. At the end of the Civil War, the vast majority of freed slaves found work as
   (A) factory workers
   (B) railroad employees
   (C) independent artisans
   (D) tenant farmers
   (E) domestic servants

6. Which of the following was the LEAST important consideration in the United States decision to drop atomic bombs on Japan in August 1945?
   (A) Dropping the bombs would give a new and powerful argument to the Japanese government to cease fighting.
   (B) Dropping the bombs would presumably shorten the war and therefore save the lives of American soldiers that would be lost in an invasion of the Japanese homeland.
   (C) Scientists could propose no acceptable technical demonstration of the atomic bomb likely to convince Japan that further fighting was futile.
   (D) Scientists wished to demonstrate to Congress that the $2 billion spent, after long debate, on the six-year Manhattan Project had not been wasted.
   (E) The President and the State Department hoped to end the war in the Far East without Soviet assistance.

Questions 7–8 refer to the following cartoon.


Sic 'em, Buck! sic 'em! I wish poor old Hickory was alive. He'd bring 'em back in no time.
If we can only get them separated from the flock we can pick their bones at our leisure.
VIRGINIA
KANSAS

7. According to the cartoon above, allowing the Southern states to leave the Union would cause
   (A) the North to be threatened by internal dissension
   (B) the Democratic party to collapse
   (C) the Southern states to be dominated by European powers
   (D) the Confederacy to expand into Latin America
   (E) President Buchanan to be impeached and removed

8. The best evidence to support the cartoonist's contention that Hickory (Jackson) would have acted to stop secession was Jackson's earlier reaction to the
   (A) election of John Quincy Adams to the presidency
   (B) Spanish and Native American (Indian) border attacks on Florida
   (C) South Carolina Nullification Ordinance
   (D) requests for annexation of Texas
   (E) Maysville Road Bill

9. The 1848 women's rights convention in Seneca Falls, New York, was a protest against
   - (A) the use of women workers in textile factories
   - (B) the abuse of slave women on Southern plantations
   - (C) the failure of the Democratic party to endorse the Women's Suffrage Amendment
   - (D) customs and laws that gave women a status inferior to that of men
   - (E) state restrictions that prevented women from joining labor unions

10. In his interpretation of the historical development of the United States, Frederick Jackson Turner focused on the importance of
    - (A) the traditions of Western European culture
    - (B) the absence of a feudal aristocracy
    - (C) black people and black slavery
    - (D) the conflict between capitalists and workers
    - (E) the existence of cheap unsettled land

11. Many Mexicans migrated to the United States during the First World War because
    - (A) revolution in Mexico had caused social upheaval and dislocation
    - (B) immigration quotas for Europeans went unfilled as a result of the war
    - (C) the war in Europe had disrupted the Mexican economy
    - (D) American Progressives generally held liberal views on the issue of racial assimilation
    - (E) the United States government recruited Mexican workers to accelerate the settlement of the Southwest

Free-Response Questions

The free-response section of the examination consists of two parts. Part A includes a document-based essay question which must be answered by all candidates. Part B includes five standard essay questions on the period from the first colonial settlements to the present, from which candidates must choose one. The following are sample questions.

Part A: Document-Based Essay Question (DBQ)

Directions: The following question requires you to construct a coherent essay that integrates your interpretation of Documents A–I *and* your knowledge of the period referred to in the question. High scores will be earned only by essays that both cite key pieces of evidence from the documents and draw on your knowledge of the period.

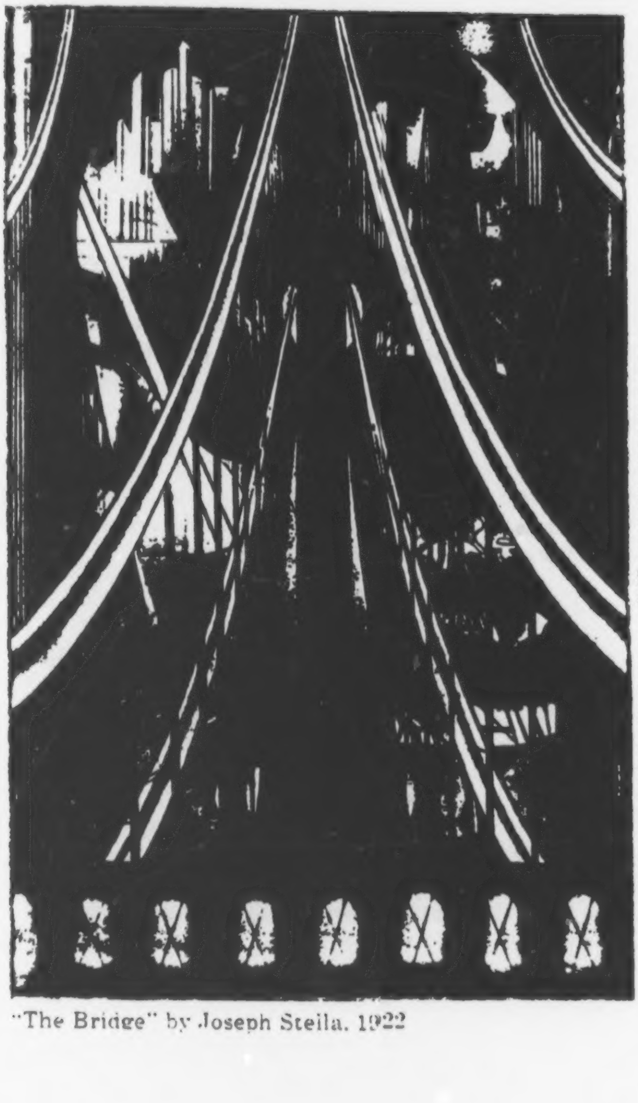
> The 1920s were a period of tension between new and changing attitudes on the one hand and traditional values and nostalgia on the other. What led to the tension between old and new AND in what ways was the tension manifested?

Document A

Just as he was an Elk, a Booster, and a member of the Chamber of Commerce, just as the priests of the Presbyterian Church determined his every religious belief and the senators who controlled the Republican Party decided in little smoky rooms in Washington what he should think about disarmament, tariff, and Germany, so did the large national advertisers fix the surface of his life, fix what he believed to be his individuality. These standard advertised wares—toothpastes, socks, tires, cameras, instantaneous hot-water heaters—were his symbols and proofs of excellence; at first the signs, then the substitutes, for joy and passion and wisdom.

Source: Sinclair Lewis. *Babbitt*. 1922

Document B



"The Bridge" by Joseph Stella, 1922

COLLECTION OF THE NEWARK MUSEUM, PURCHASE 1937 FELIX FULD BEQUEST FUND

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Document C

Mr. Darrow: Do you claim that everything in the Bible should be literally interpreted?

Mr. Bryan: I believe everything in the Bible should be accepted as it is given there; some of the Bible is given illustratively. For instance: "Ye are the salt of the earth." I would not insist that man was actually salt, or he had flesh of salt, but it is used in the sense of salt as saving God's people.

• • •

Mr. Darrow: But when you read that Jonah swallowed the whale—or that the whale swallowed Jonah—excuse me please—how do you literally interpret that? . . .

Mr. Bryan: One miracle is just as easy to believe as another . . . .

Mr. Darrow: Perfectly easy to believe that Jonah swallowed the whale? . . .

• • •

Mr. Bryan: Your honor, I think I can shorten this testimony. The only purpose Mr. Darrow has is to slur at the Bible, but I will answer his question. I will answer it all at once, and I have no objection in the world. I want the world to know that this man, who does not believe in God, is trying to use a court in Tennessee—

Mr. Darrow: I object to that

Mr. Bryan: (Continuing) to slur at it, and while it will require time, I am willing to take it.

Mr. Darrow: I object to your statement. I am examining you on your fool ideas that no intelligent Christian on earth believes.

Source: *The World's Most Famous Trial: Tennessee Evolution Case*, 1925

Document D

We are a movement of the plain people, very weak in the matter of culture, intellectual support, and trained leadership. We are demanding, and we expect to win, a return of power into the hands of the everyday, not highly cultured, not overly intellectualized, but entirely unspoiled and not de-Americanized, average citizen of the old stock. Our members and leaders are all of this class—the opposition of the intellectuals and liberals who held the leadership, betrayed Americanism, and from whom we expect to wrest control, is almost automatic.

This is undoubtedly a weakness. It lays us open to the charge of being "hicks" and "rubes" and "drivers of second-hand Fords." We admit it. Far worse, it makes it hard for us to state our case and advocate our crusade in the most effective way, for most of us lack skill in language.

• • •

The Klan, therefore, has now come to speak for the great mass of Americans of the old pioneer stock. We believe that it does fairly and faithfully represent them, and our proof lies in their support. To understand the Klan, then, it is necessary to understand the character and present mind of the mass of old-stock Americans. The mass, it must be remembered, as distinguished from the intellectually mongrelized "Liberals."

These are, in the first place, a blend of various peoples of the so-called Nordic race, the race which, with all its faults, has given the world almost the whole of modern civilization. The Klan does not try to represent any people but these.

Source: Hiram Wesley Evans, "The Klan's Fight for Americanism," *The North American Review*, March 1926

Document E

Jazz to me is one of the inherent expressions of Negro life in America: the eternal tom-tom beating in the Negro soul—the tom-tom of revolt against weariness in a white world, a world of subway trains, and work, work, work; the tom-tom of joy and laughter, and pain swallowed in a smile. Yet the Philadelphia clubwoman . . . turns up her nose at jazz and all its manifestations—likewise almost anything else distinctly racial. . . . She wants the artist to flatter her, to make the white world believe that all Negroes are as smug and as near white in soul as she wants to be. But, to my mind, it is the duty of the younger Negro artist . . . to change through the force of his art that old whispering "I want to be white," hidden in the aspirations of his people, to "Why should I want to be white? I am Negro—and beautiful."

Source: Langston Hughes, "The Negro Artist and the Racial Mountain," *The Nation*, 1926

Document F

When, because of what we believe him to be, we gave Lindbergh the greatest ovation in history, we convicted ourselves of having told a lie *about* ourselves. For we proved that the "things of good report" are the same today as they were nineteen hundred years ago.

We shouted ourselves hoarse. Not because a man had flown across the Atlantic! Not even because he was an American! But because he was as clean in character as he was strong and fine in body; because he put "ethics" above any desire for wealth; because he was as modest as he was courageous; and because—as we now know, beyond any shadow of doubt—*these are the things which we honor most* in life.

To have shown us this truth about ourselves is the biggest thing that Lindbergh has done.

Source: Mary B. Mullett, "The Biggest Thing That Lindbergh Has Done," *The American Magazine*, October, 1927

Document G

Be it resolved, that the National W.C.T.U. [Women's Christian Temperance Union] encourages further scientific research into the effects of nicotine and urges all public and private school teachers and Sunday school workers, both by precept and example, to assist in an educational campaign to make these effects known with a view to instructing the youth as to the well-proven facts of science; and

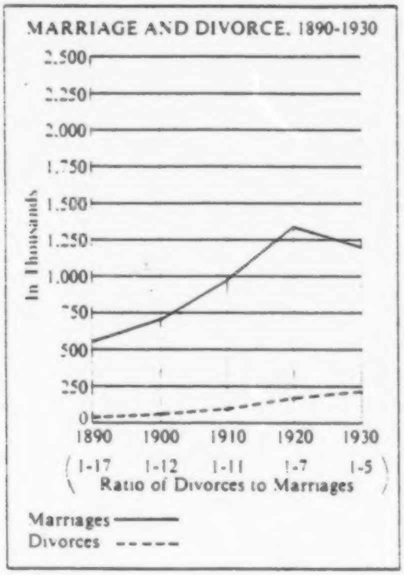
Be it further resolved, that the national W.C.T.U. brands as untrue the charge made by the Association Opposed to National Prohibition that we are engaged in a secret campaign for an amendment to the Constitution prohibiting tobacco. . . .

[Mrs. Ella A. Boole, President of the New York State organization says:]

"We are working on this question from a scientific standpoint and from an educational standpoint. After all, the duty of motherhood is still relegated to the women of the nation. Just as long as that is true we must protect the coming generation by teaching the present one the effects of the habit of smoking on the unborn. . . ."

Source: "Women Smokers," *The New York Times*, February 29, 1928

Document H



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Document I

. . . Sister substituted the Gospel of Love for the Gospel of Fear. This doctrine was as strange in Southern California as it is elsewhere in Christendom. . . .

Sister substituted the cheerfulness of the play-room for the gloom of the morgue. She threw out the dirges and threats of Hell, replacing them with jazz hymns and promises of Glory. The gospel she created was and is an ideal bed-time story. It has a pretty color, a sweet taste, and is easy.

• • •

Mrs. McPherson describes the Holy City literally—the jewelled walls, pearly gates, golden streets, milk and honey. She says she is not sure—she is not *sure*, mind you—but she has a pretty good idea that Heaven will resemble a cross between Pasadena, California, and Washington, D.C. That will give an idea of what may be expected at Angelus Temple. The atmosphere bubbles over with love, joy, enthusiasm; the Temple is full of flowers, music, golden trumpets, red robes, angels, incense, nonsense and sex appeal. The service may be described as supernatural whoopee.

Source: Morrow Mayo, "Aimee Rises from the Sea," *The New Republic*, December 25, 1929

End of Documents for Question 1.

Part B: Standard Essay Questions

Directions: You are to answer ONE of the following five questions. Carefully choose the question that you are best prepared to answer. Cite relevant historical evidence in support of your generalizations and present your arguments clearly and logically. When you finish writing, check your work if time permits. Make certain to number your answer as the question is numbered below. Please write your answers with a pen.

1. "Despite the view of some historians that the conflict between Great Britain and its thirteen North American colonies was economic in origin, in fact the American Revolution had its roots in politics and other areas of American life."

   Assess the validity of this statement.

2. In the first half of the nineteenth century, the American cultural and intellectual community contributed to the development of a distinctive American national consciousness.

   Assess the validity of this statement.

3. "Both the Mexican War and the Spanish-American War were premeditated affairs resulting from deliberately calculated schemes of robbery on the part of a superior power against weak and defenseless neighbors."

   Assess the validity of this statement.

4. Andrew Carnegie has been viewed by some historians as the "prime representative of the industrial age" and by others as "an industrial leader atypical of the period."

   Assess the validity of each of these views.

5. "Reform movements of the twentieth century have shown continuity in their goals and strategies."

Assess the validity of this statement for ONE of the following pairs of reform movements.

Progressivism and the New Deal

Woman's suffrage and post-Second World War Feminism

The New Deal and the Great Society

The Science Objectives for the 1972-73 Science Assessment of the National Assessment of Educational Progress (NAEP)

ELEMENTS OF SCIENTIFIC LITERACY: A TWO-DIMENSIONAL GRID USED IN THE ORGANIZATION OF THE SCIENCE OBJECTIVES

	Fundamental Aspects of Science				
Objectives	Facts and Simple Concepts	Laws (Principles)	Conceptual Schemes	Inquiry Skills	The Scientific Enterprise
Know	(I A)	(I B)	(I C)	(I D)	(I E)
Understand and Apply	(II A)	(II B)	(II C)	(II D)	(II E)
Appreciate	(III A)			(III B)	(III C)

1. Know that laws (principles) of science and technology apply to the solution of problems relating to human welfare. Examples of such problems are conservation of natural resources, environmental pollution, food supply, highway safety, population control, and radiation and fallout.

2. Recognize how scientific knowledge can develop.

   For example, recognizes that scientific knowledge can develop both inductively (by observation and experiment and the interpretation of the observations and experimental results) and deductively (by predictions made from existing theories); recognizes that observations and experiments are subject to critical examination, replication, and human error; recognizes that science is both a means and an end.

Age 9	Begins to recognize that science is essentially a search for understanding of the natural world and that it must continually relate itself to observations of that world; recognizes the need for replication in both observations and experiments.
Age 13	Recognizes the need for making relevant, controlled, and accurate observations of natural phenomena under investigation.
Age 17	Recognizes that science observations and experiments must be directed intelligently and proceed within a logical theoretical framework; recognizes that the scientific approach enables one to make sense out of experimental data and to organize it into a comprehensible body of knowledge.
Adult	Recognizes that the process of science continually requires a return to the natural phenomenon under investigation for further observations and experiments; recognizes that no natural phenomenon is so completely understood that it is beyond the province of further observation and experimentation.

3. Know that pure science is a search for basic knowledge and that applied science (technology) is a search for uses of knowledge.

Age 9	None.

Age 13 Knows that some research is conducted to develop practical uses for new or old materials; knows that new basic knowledge can come from any research.

Age 17 and Adult Identifies scientific projects in current news items as projects in pure science or in applied science.

4. Know some of the historical aspects of the sciences and technology.

   a. Identifies important living and nonliving scientists with their contributions.

   b. Knows that scientific and technological developments depend on the prevailing cultural, economic, social, and political conditions.

   c. Knows that the events of history have contributed to the scientific enterprise.

   d. Recognizes the historical sequence of some of the major scientific events; recognizes the cumulative nature of history and of knowledge in science.

5. Recognize that most questions are amenable to inquiry by scientific methods.

Age 9 Recognizes that questions differ in complexity.

Age 13 Recognizes that some questions are much more difficult to investigate than others by scientific methods.

Age 17 Recognizes that some topics for scientific inquiry are more feasible than others and that considerations such as time, urgency, and resources lead to scientific inquiry in some areas but not in others: recognizes that some topics do not qualify as subject matter for science (that is, that for some topics, observations and experiments cannot be made or the results of some observations and experiments are a function of the individual investigator).

Adult Recognizes that religious and social issues are involved in some areas of scientific and technological endeavor: knows that the public interest in, concern about, and moral and material support of scientific inquiry differ greatly depending on the urgency, practicality, and relevance of the inquiry.

6. Recognize that measurement is an important feature of science.

For example, recognizes that the formulation and establishment of laws (principles) are facilitated through the development of quantitative distinctions; recognizes that measurements are approximate by nature and are progressively inclusive and precise.[1]

Age 9 Knows that quantitative measurements of natural phenomena can be made.

Age 13 Knows that quantitative measurements provide clearer and more precise representations of natural phenomena than do qualitative descriptions.

Age 17 Knows that quantitative measurements, when feasible, provide the basis for description, hypothesis testing, and prediction; identifies mathematics and statistics as valuable tools for deriving information from quantitative data; knows that all data are not equally precise.

Adult Knows the importance of quantitative measurement in scientific inquiry; recognizes that all measurement is approximate.

7. Recognize that science is not, and probably never will be, a finished enterprise.[2]

Age 9 Knows that man has always had questions of a scientific nature to explore.

Age 13 Knows that scientific ideas are subject to change and that scientists search continually for the answers to questions.

Age 17 Knows that man continually modifies theories and laws (principles) based on new information, and that scientific theories evolve and are subject to change over a period of time.

---

[1] National Science Teachers Association. *Theory Into Action.* Washington, D. C.: NSTA, 1964.

[2] National Science Teachers Association. *op. cit.*

Adult Knows that science is always in a state of change and that as new information and technical skills are developed, our present-day scientific knowledge is refined to a greater degree.

8. Have accurate perceptions about scientists as people.

   a. Perceives what scientists are like as people: perceives that their lives and personalities are similar to those of other people and as varied as those of other people.

   b. Perceives the role of scientists as that of uncovering and developing knowledge; knows that there are limitations on what scientists can do; has realistic perceptions of the abilities and power of scientists.

   c. Recognizes the nature of the training and/or experience (sometimes extensive) needed by scientists and technologists.

II. *UNDERSTAND AND APPLY THE FUNDAMENTAL ASPECTS OF SCIENCE IN A WIDE RANGE OF PROBLEM SITUATIONS*

To "understand" is to be able to explain in one's own words, to recognize when stated in phraseology different from that in the textbook, to interpret (such as in interpreting tables or graphs of data), and to draw inferences from. To "apply" is to make actual use of previously acquired knowledge. One must have knowledge and understand that knowledge before it can be applied.

* * *

E. *Understand and apply the scientific enterprise.*

Have a valid understanding of the scientific enterprise and give evidence of that understanding in one's behavior. Make enlightened use of this understanding of the scientific enterprise.

For example, use this understanding in attempting to interpret everyday occurrences, in guiding daily activity, in personal decision making, and in attacking the problems of society as a whole.

1. Have enlightened understanding of the social and economic consequences of the scientific enterprise.

For example, understands the impact of science and technology on society and the impact of society on science and technology; is aware of the ethics that control the scientist and his work; perceives both the advantages and the dangers of scientific and technological proposals and developments; applies an understanding of the scientific enterprise in evaluating, judging, and working to solve problems relating to human welfare, such as conservation of natural resources, environmental pollution, food supply, highway safety, population control, and radiation and fallout.

2. Make appropriate generalizations about the development of scientific knowledge.

For example, understands that laws (principles) can come about by generalization from observations or by deduction from theories; understands that theories can come about by generalization from laws (principles).

Age 9 Describes the meaning of the definition of science as essentially a search for knowledge; explains the purpose of observations in this search; describes the need for replication in both observations and experiments.

Age 13 Describes the need for relevant, controlled, and accurate observations of natural phenomena under investigation.

Age 17 Understands that science depends on relevant and accurate observations and experiments, and that these observations and experiments must be directed intelligently and proceed within a logical theoretical framework; understands that the scientific approach enables one to make sense out of experimental data and to organize it into a comprehensible body of knowledge; realizes that scientific knowledge is tentative in nature.

Adult Understands that the process of science continually requires a return to the natural phenomenon under investigation for further observations and experiments; comprehends that no natural phenomenon is so completely understood that it is beyond the province of further observation and experimentation.

3. Distinguish between pure science and applied science (technology).

Age 9 None.

Age 13 Begins to distinguish between research for basic knowledge and research for practical uses. For example, given a list of familiar research topics, distinguishes between those which are pure science and those which are technology; realizes that relatively few scientists discover new information but that many technologists develop the consequences of this information.

Age 17 and Adult Cites examples of projects which could be considered as pure science and projects which could be considered as technology; describes research mentioned in current news items as basic research or as applied research.

4. Use historical information about the sciences to understand present-day science and technology. An example of such historical perspective is the following: although Newton delineated the scientific principles of putting a satellite into orbit 300 years ago, it has taken much of the time since then to develop the technology to do so.

5. Understand that most questions are amenable to inquiry by scientific methods.

Age 9 Orders questions that differ in complexity.

Age 13 Describes why some questions are much more difficult to investigate than others by scientific methods.

Age 17 Describes why some topics for scientific inquiry are more feasible than others and how considerations such as time, urgency, and resources lead to scientific inquiry in some areas but not in others; explains that some topics do not qualify as subject matter for science; (that is, that for some topics observations and experiments cannot be made or the results of some observations and experiments are a function of the individual investigator).

Adult Describes the religious and social problems involved in some areas of scientific and technological endeavor; understands that the public interest in, concern about, and moral and material support of scientifc inquiry differ greatly depending on the urgency, practicality, and relevance of the inquiry.

6. Understand that measurement is an important feature of science.

For example, understands that the formulation and establishment of laws (principles) are facilitated through the development of quantitative distinctions: understands that measurements are approximate by nature and are progressively inclusive and precise. [3]

Age 9 Understands that quantitative measurements of natural phenomena can be made.

Age 13 Describes how quantitative measurements provide clearer and more precise representations of natural phenomena than do qualitative descriptions.

Age 17 Explains or demonstrates that quantitative measurements, when feasible, provide the basis for description, hypothesis testing, and prediction: explains that mathematics and statistics provide valuable tools for deriving information from quantitative data: explains that all data are not equally precise.

Adult Understands that measurement is important in scientific inquiry and that all measurement is approximate and varies in precision and accuracy.

7. Understand that science is not, and probably never will be, a finished enterprise.[4]

Age 9 Understands that man has always had questions of a scientific nature to explore.

Age 13 Understands that scientific ideas are subject to change and that scientists search continually for the answers to questions.

Age 17 Understands that man continually modifies theories and laws (principles) based on new information, and that scientific theories evolve and are subject to change over a period of time.

---

[3] National Science Teachers Association, *op. cit.*

[4] National Science Teachers Association, *op. cit.*

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Adult Understands that science is always in a state of change and that as new information and technical skills are developed, our present-day scientific knowledge is refined to a greater degree.

8. Interacts with scientists as with any other people, without the unrealistic expectations, fears, or reverence which would follow from categorization and stereotyping.

III. *APPRECIATE THE KNOWLEDGE AND PROCESSES OF SCIENCE, THE CONSEQUENCES AND LIMITATIONS OF SCIENCE, AND THE PERSONAL AND SOCIAL RELEVANCE OF SCIENCE AND TECHNOLOGY IN OUR SOCIETY*

To "appreciate" is to value objects, ideas, and processes. Appreciation is expressed behaviorally in willingness to attend, to give up resources for, to take a stand in favor of, etc. One must "know about" in order to appreciate, although he need not necessarily "understand."

* * *

C. *Appreciate the scientific enterprise.*

Have one's value system affected by his understanding of the scientific enterprise. Appreciate the need for, and value, the activities and products of science.

1. Appreciate the nature of the scientific enterprise, especially seeing its emphasis on reason and its opposition to mystical explanation as profoundly shaping the history of western civilization.

   For example, appreciates the distinction between science and superstitions or misconceptions and develops reliance on the former; possesses scientific attitudes such as the following (which may be formed relatively early in intellectual development):

   a. skepticism of mystical explanations (for example, horoscopes).

   b. preference for and confidence in scientific explanations.

c. faith in the possibility of solving problems.

d. desire for experimental testing.

e. delight in the richer, more exciting view of the world generated by science education.

2. Appreciate the interrelationships within the various branches of science and between science and other disciplines (including the humanities).

   For example, perceives mathematics as the language of science. Enjoys the personal discovery of such relationships.

3. Appreciate the interrelationships between pure and applied science.

   For example, values both pure and applied science, aware of their different roles.

4. Appreciate scientists; acknowledge the role of scientists in working for solutions to present-day problems; acknowledge the respected place of various scientists esteemed throughout history. Believe scientists are valuable people.

5. Show appreciation of and interest in scientific activities.

   For example, engages in science-related leisure-time activities commensurate with own age level, the activities being somewhat independent of school or job requirements (that is, these self-initiated activities may or may not have been stimulated or suppressed by the school or job); remains educable in science.

   Age 9 Shows a desire for inquiring about matters such as transportation, construction, techniques of science, astronomy, and industrial processes; begins to show development of interest and curiosity through questions raised about weather, the sky, the earth, living things, machines, transportation, communication, and the natural world; shows interest in science stories, pictures of animals and plants from various regions, conservation, protection of birds and birds' nests, and the making of science collections; begins to develop pride in good workmanship, in

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Toronto Benchmarks

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FIGURE 7: BENCHMARK L3-6: OWLS (excluding video)

TORONTO BOARD OF EDUCATION

B | E | N | C | H | M | A | R | K | S

STANDARDS OF STUDENT ACHIEVEMENT

L3 6

Grade 3 Language
Video

Number 6 of 16
Benchmarks

Key Objectives from the Ontario Ministry of Education and Toronto Board Guidelines

- Listen with sensitivity and discrimination
- Develop visual awareness, sensitivity and appreciation
- Acquire an understanding of oral reports
- Articulate his or her own ideas, thoughts and feelings with confidence and lucidity

OWLS

Viewing (Television) & Oral Retelling

This Benchmark was developed to assess students' ability to comprehend non-print information and to retell it orally. A selection from Owl TV, about owls being cared for in a sanctuary, was chosen. Students' oral retelling was scored holistically.

Students who did well in this activity provided a good summary of the information in the video with many details presented in sequence. They understood the difficult concept of imprinting and were able to explain it in their own words. These students used information presented both orally and visually in the video.

Before the activity, students were asked questions about owls and were then rated for prior knowledge and experience and the ability to predict the content of the video. The students were asked to view the seven-minute television video. When the video was finished, the students were asked to tell what it was about in their own words. When students seemed to have difficulty, the evaluators asked questions or provided prompts to encourage them to continue. Understanding of the concept of imprinting as it was explained in the video was explored. Upon completion, the students were asked to rate the activity in terms of ease of understanding the video and ease of telling about it. They were also asked to give one new fact that they had learned from the video.

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FIGURE 7 (continued)

B|E|N|C|H|M|A|R|K|S

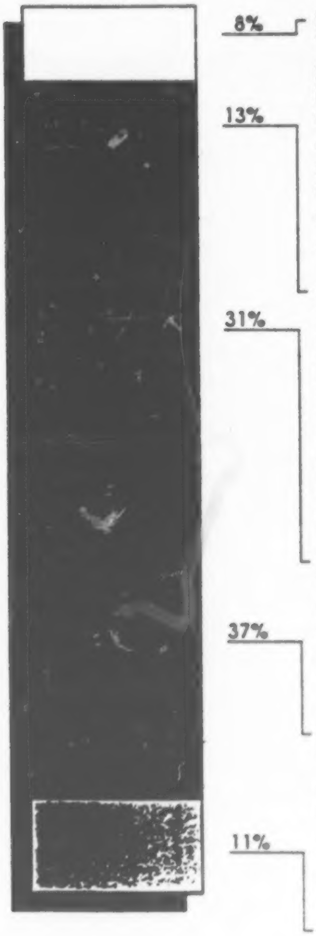
STANDARDS
OF
STUDENT
ACHIEVEMENT

TORONTO
BOARD
OF
EDUCATION

L3 **6** **Grade 3 Language**
Video

OWLS

RANGE OF RESPONSES **HOLISTIC SCORING CRITERIA**



LEVEL FIVE
The student demonstrates understanding of the concepts presented in the video and is able to use information which has been presented both orally and visually. Ability to go beyond the text is exhibited by making inferences and drawing conclusions. The concept of imprinting is explained spontaneously or with prompting. The student is able to use the language of the video precisely to discuss the information. Quotes and paraphrases are frequently used. The student expresses ideas confidently and freely.

LEVEL FOUR
The student demonstrates understanding of the video. Information which has been presented orally and visually in the video is drawn upon. When prompted, the student makes inferences and is able to explain the concept of imprinting. There may be an attempt to organize and summarize the information. Events may be recounted in sequence. The student attempts to use the vocabulary used in the video but may experience some difficulty in articulating specific information.

LEVEL THREE
The student demonstrates some understanding of the information in the video. Recounting of information tends to be repetitive, disjointed and limited. Even with prompting, the information given may be very general and misinterpreted. The concept of imprinting is not understood.

LEVEL TWO
The student gives a random, disorganized and sparse account of information from the video. Even when prompted, the information may be sparse, inaccurate or vague. Major concepts do not appear to be understood. The student seems very dependent on the evaluator. Answers to questions from the evaluator tend to be one-word.

LEVEL ONE
The student is unable to tell about the video or to respond to questioning about it.

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FIGURE 7 (continued)

B|E|N|C|H|M|A|R|K|S

STANDARDS
OF
STUDENT
ACHIEVEMENT

TORONTO
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EDUCATION

L3 6 **Grade 3 Language**
Video

OWLS

OTHER FINDINGS

Several other factors which are related to student performance or have implications for teaching were also analyzed and documented.

The average total retelling time was **2.9 minutes** within a range of 1 to 9 minutes; 68% of the students did the retelling in a time frame ranging from 2.0 to 3.8 minutes.

On scales of 1 to 10, these average ratings were assigned to students by the evaluators:

• prior knowledge	5.9	• perseverance	6.6
• prior experience	5.7	• confidence	6.7
• ability to predict content	5.5	• willingness	7.5

On scales of 1 to 10 (where 10 is very easy), these average ratings were assigned by students as their evaluations of the activity:

• ease of understanding the video	7.7
• ease of telling about the video	7.1

- Students who did well in the oral retelling tended to have high ratings for ability to predict content, perseverance, confidence and willingness (moderate correlations).
- Students who thought the video was easy to tell about tended to think it was easy to understand (a moderate correlation).

CONCLUDING QUESTION

In conclusion, to refocus on the video as a whole, students were asked to give one new fact that they had learned. They gave some variation of sixty different answers. Of the total, 20% of the students attempted to articulate the difficult concept of imprinting and 6% of the students attempted to articulate other difficult concepts related to owls. The majority of the students, 67%, focussed on explicit details such as how owls eat mice. The remaining 7% of the students gave no answer or said they had learned nothing new.

Owls from Owl T.V. co-produced by Owl and The National Audobon Society, Greey de Pencier, Toronto.

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FIGURE 9: BENCHMARK M6-8: POURING WATER (excluding video)

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B | E | N | C | H | M | A | R | K | S

STANDARDS OF STUDENT ACHIEVEMENT

M6 8

Grade 6 Mathematics
Video

Number 8 of 27
Benchmarks

Key Objectives from the Ontario Ministry of Education and Toronto Board Guidelines

- **Estimate capacity and volume with appropriate degree of precision**
- **Demonstrate measurement skills involving the use of various instruments**

POURING WATER

Estimating and Measuring Capacity and Volume

Several tasks were designed to formulate this Benchmark.

A. Capacity

This activity is demonstrated on the videotape.

The first task required that students estimate, then measure, how much water a large container (3 L) would hold. This was followed by asking students to estimate and then measure how much water a small container (250 mL) would hold. For measuring each container students were provided with a basin of water and a calibrated litre cylinder.

Students who did well on these tasks gave close estimates and measured accurately and efficiently. They demonstrated a good grasp of the concepts and skills involved. They showed confidence and enjoyed the challenge presented by the tasks.

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FIGURE 9 (continued)

B|E|N|C|H|M|A|R|K|S

STANDARDS
OF
STUDENT
ACHIEVEMENT

TORONTO
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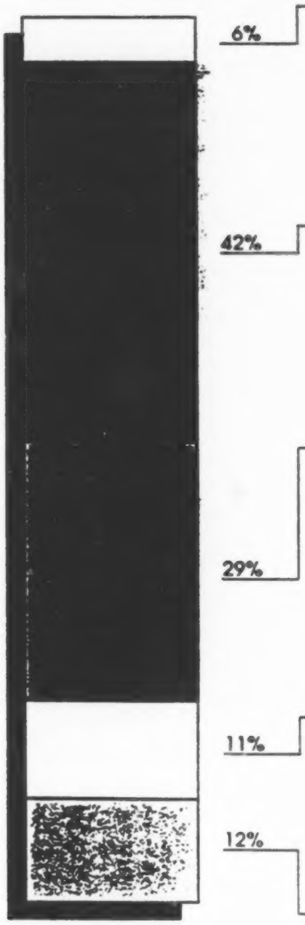
EDUCATION

M6 **8** Grade 6 Mathematics
Video

POURING WATER

RANGE OF RESPONSES

HOLISTIC SCORING CRITERIA



LEVEL FIVE
The student uses correct methods to measure accurately and efficiently with water. Measures are made with the containers on the level and part measures are monitored and recorded. Measures are done quickly and with confidence. The student is fluent in metric units and includes appropriate units without prompting. The student gives close estimates.

LEVEL FOUR
The student may experiment to find correct methods to measure with water usually arriving at correct results. The student may be inconsistent in methods used to measure and units chosen. There may be an initial confusion concerning the task but the student may learn as the task proceeds. Initial estimates are usually in appropriate units but are not close.

LEVEL THREE
The student has a weak understanding of how to measure with water. Measures are made perhaps without awareness of the need for accuracy and completeness; methods may be changed as the student proceeds with the task. Units are confused at times or not used appropriately. There may be some inefficiency in the measuring such as losing track of "part" measures. Estimates indicate an incomplete understanding of underlying concepts. Some coaching is required.

LEVEL TWO
The student uses inefficient methods to measure or changes methods to no apparent advantage. Measures are inaccurate and incomplete. The student is confused about units and may count the units on the graduated cylinder. Estimates indicate very little understanding of underlying concepts. The student needs to be coached.

LEVEL ONE
The student does not understand the problem or forgets the assigned task.

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FIGURE 9 (continued)

B|E|N|C|H|M|A|R|K|S

STANDARDS
OF
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B. Volume

This task is not demonstrated on the videotape.

In another task for this Benchmark, students were shown a box without a lid; its dimensions were 10 cm x 8 cm x 5 cm. The students were asked to estimate the volume of the box and, where necessary, were prompted for units by being shown a cubic centimetre. After their estimates, students were provided with 8 interlocking centimetre cubes and were asked to check their estimates by measuring. Here are the results:

Estimating

Students' estimate of the volume of the box before the prompt:	163 different responses	
	between and including 300 cm^3 and 500 cm^3	5%
	between and including 300 and 500 (no units)	7%
	between and including 200 cm^3 and 600 cm^3	8%
	between and including 200 and 600 (no units)	11%
	other estimates in cm^3 or cubes	17%
	no response	19%

Students needing prompt to give volume in cubic centimetres	69%

Measuring

Students method for checking estimate:	correctly measured and multiplied width x length x height (answer may not have been correct)	37%
	incorrectly measured and multiplied width x length x height	12%
	other methods	35%
	no response	16%

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FIGURE 9 (continued)

BENCHMARKS

STANDARDS
OF
STUDENT
ACHIEVEMENT

TORONTO
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EDUCATION

8

Grade 6 Mathematics
Video

POURING WATER

OTHER FINDINGS - CAPACITY

Large Container (3 L)

- **Students' estimates of how much water it would hold:**

between and including 2.5 L and 3.5 L	11%
between and including 2.0 L and 4.0 L	22%
3 L	7%
2 L	8%
1.5 L	7%
1 L	11%
no response	16%

- **If students responded with an estimate which was not in litres, they were asked, "How many litres would the container hold?". 52% of the students needed this prompt.**

- **Students' measurements for 3 L container:**

3 L	35%
between and including 2.75 L and 3.25 L	64%

Small Container (250 mL)

- **There are no reliable data for estimating and measuring the small container.**

OTHER REFERENCES

Additional information can be found in Benchmarks M6-20, Converting Measurements Among Metric Units; and M3-24, Visualizing Cube Arrangements.

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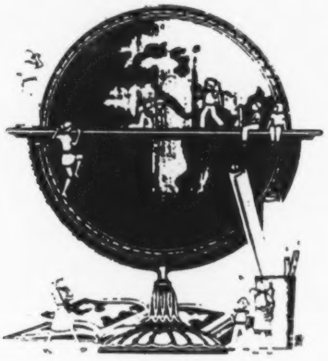
The Geography Objectives for the 1988 Geography Assessment, National Assessment of Educational Progress (NAEP)

For example, the domain of Geographic Skills and Tools is discussed independently of the domains of Physical and Cultural Geography—an artificial distinction, given that a variety of map and resource skills is vital to a student's understanding of both content domains. Similarly, the separate treatment of Physical and Cultural Geography emphasizes that not only physical phenomena, but also human, political, and economic factors are important to geographic study. Finally, the independent discussion on Geographic Inquiry highlights the ability to apply skills and understanding to investigate particular aspects of physical and cultural relationships.

Together, the three dimensions—Geographic Skills and Tools, Geographic Knowledge and Concepts (Content), and Geographic Inquiry—offer a framework for defining objectives in geography education and for developing exercises to assess students' geographic understanding at age 17/grade 12. Curriculum developers may also find the framework useful in examining their own priorities in instruction. A broader K-12 perspective on curriculum is offered in the *Guidelines for Geographic Education* (1984), prepared by the Joint Committee on Geographic Education of the National Council for Geographic Education and the Association of American Geographers.



Chapter two

The Geography Objectives

The Learning Area Committee did not intend that the following objectives be considered complete or definitive or to imply that any curriculum should include all specified topics. However, the included areas were deemed central to geography instruction and were designed to guide the development of questions for the assessment. A table containing the approximate percentage distribution of questions can be found at the end of Chapter Two.

GEOGRAPHIC SKILLS AND TOOLS

This domain encompasses the skills and tools essential to the study of geography, ranging in sophistication from basic map-reading abilities (e.g., understanding direction, symbols, scale, and location) to recognizing the purposes of different symbolic representations and interpreting thematic maps, graphs, and photographs. Maps and globes are fundamental methods of communicating complex social and physical data, and are considered primary geography tools.

The concept of region is also an important organizing tool in geography. Geographers define regions in many different ways; a region may be demarcated by physical features, such as grasslands and mountain ranges, or by cultural features, such as language, political system, or religion. However defined, the region is a basic unit of study for all domains of geography, and is often used as the organizational framework for high school geography courses. Students should be able to:

a) Recognize and interpret map and globe symbols (e.g., direction and orientation).

b) Use scales to measure distance and area.

c) Use coordinates of latitude and longitude to determine absolute location.

d) Determine and explain relative location (e.g., direction, accessibility, and landmarks).

e) Understand that any flat map is a distortion of a round surface and that different projections serve different purposes.

f) Recognize and interpret thematic maps (e.g., cartograms or dot maps of topography, population, or commodities).

g) Detect patterns and determine relationships across maps.

h) Read and interpret graphs (e.g., population pyramids and climagraphs) and charts.

i) Recognize that the earth is divided into northern and southern hemispheres by the equator.

j) Understand that regions provide manageable spatial units for geographic analysis.

GEOGRAPHIC KNOWLEDGE AND CONCEPTS (Content)

Physical Geography

Within the study of geography, the subdiscipline of physical geography focuses on the configuration of the earth's surface, including major topographical features, soil, vegetation, and atmospheric changes. When interactions take place among these phenomena, changes occur in the physical environment, often creating a need for different patterns of human adaptation.

Geographers strive to explain the origin and significance of physical landscapes, particularly as they influence human activity. Among the topics used by geographers to more fully explain the physical environment are:

★location, place, and region;

★climatology and meteorology; and

★evolution of the earth's features.

Knowledge of these specific topics provides a basis for better understanding the physical world and its dynamic forces.

Location, Place, and Region

All physical features have **absolute locations** on earth, and these provide useful information in geographic study. For example, researchers who want to study the Mount St. Helens volcano need to know its absolute location as identified by latitude and longitude. Although such knowledge is useful, it is often necessary to have more detailed information in order to develop or convey an adequate description of a particular site.

Relative location is used to provide more referential information. For example, in identifying the relative location of Mount St. Helens, one might say that it is in the southwestern quadrant of Washington State, about 50 miles from the Oregon border, and is one of a series of volcanic peaks in the Cascade Range. Similarly, a description of the relative location of the Tibetan Plateau would likely include the referent of the Himalaya Mountains, and Lake Tanganyika in Africa might be described relative to the location of the Great Rift Valley. Thus, relative location can be used to communicate relevant information by describing a site in its spatial context.

In contrast to locations, **places** may be characterized by physical and cultural features, such as climate, weather, geology, and patterns of settlement. Places across the earth are interconnected by virtue of their physical and cultural features. Knowing how these features are related helps to account for spatial variations and interactions within and between places. For example, knowing that Mount St. Helens is sited along a chain of active volcanoes contributes to our understanding of why this particular volcano erupted where it did and the consequences of this activity.

The concept of **region** was developed by geographers to identify a common set of features of an area—human or physical—that distinguish it from other areas. In physical geography, regions are defined by the interaction of physical phenomena in an area. The tropical rain forest of the Amazon basin of Brazil constitutes a physical region because of the uniformity in climate, soils, and vegetation within that area. The Rocky Mountains form a region based on the characteristics of common earth-building processes. Knowledge of the shared features of an area allows the geographer to study and analyze sections of the earth's surface and to make comparisons across different areas.

Students should be able to identify and locate:

a) Major continental land masses and major ocean basins.

b) Selected rivers, lakes, gulfs, and seas (e.g., Nile, Amazon, Mississippi, Yangtze, the Ganges, Great Lakes, Gulf of Mexico, Persian Gulf, and the Mediterranean).

c) Major land forms (e.g., Great Plains, Rockies, Alps, Andes, and Himalayas).

d) Major climatic regions and ecosystems (e.g., tropical rain forests, Mediterranean region, desert, and polar).

e) Deposits of natural resources on maps and charts (e.g., oil, coal, water, iron ore, uranium, fisheries, forests, and soils).

Climatology and Meteorology

Studying climatology and meteorology, and their reciprocal relationships with environmental features.

provides another basis for understanding physical geography. For example, the burning of fossil fuels and the destruction of tropical rain forests contribute to an increase in the carbon dioxide concentration in the atmosphere which, in turn, contributes to an increase in the earth's average temperature (known as the greenhouse effect). This climatic change may also initiate or exacerbate other environmental consequences.

Students should be able to understand:

a) How earth/sun relationships affect climate (e.g., heating, wind, and ocean currents) and time (e.g., days and seasons), including differential effects for the hemispheres.

b) The reciprocal relationships among climate, soils, and vegetation.

c) Various atmospheric pressure conditions as they relate to local and global patterns of wind and precipitation.

Evolution of Land-Form Features of the Earth's Surface

Students should also be familiar with the basic tectonic and erosion processes that influence the **evolution of the earth's features**. For example, mountains may be formed by the movement of plates, valleys carved out by erosion, and islands developed through vulcanism or by volcanic activity. An understanding of these and other major processes is essential to a grasp of the evolution and transformation of the earth's topographical features.

Students should be able to understand:

a) Basic tectonic processes (e.g., folding, faulting, warping, vulcanism, and plate rearrangement).

b) Basic erosion processes (e.g., weathering, degradation, and aggradation).

Cultural Geography

The subdiscipline of cultural geography seeks to explain the origin, spatial distribution, and importance of human settlements and activities. It emphasizes the ways in which society has changed the natural landscape or environment into modified or cultural landscapes. For example, since the beginning of the human race on earth, people have created shelters, clothing, tools, weapons, and medicines that have allowed them to adapt to or transform their existing environments.

Cultural geography directs attention to the origin, distribution, and influence of those elements of culture — such as economics, technology, aesthetics, and religion — that give expression to a given landscape. The goal of this subdiscipline is to make sense of the ways in which human systems have altered, and been influenced by, various environments or landscapes.

Four major topics are used by geographers to organize and structure their explanation of the human role in landscape manipulation. These topics include:

★location, place, and region;

★human impact on the environment;

★influence of environment on human activity; and

★spatial interaction.

Location, Place, and Region

As with physical geography, the concepts of **location**, **place**, and **region** are critical to the study of cultural geography. For example, the ability to identify major American cities, states, and regions; foreign countries; prominent cultural regions; areas of low and high population density; and areas with different patterns of economic development should help to promote an understanding of the basics in geography and in other subject areas, such as history and economics. Students should be able to identify:

a) The 50 states and major cities in the United States (e.g., Washington, D.C.; New York; Boston; Chicago; Los Angeles; and Dallas).

b) Major countries (e.g., Canada, Mexico, the Soviet Union, China, India, Nigeria, Peru, and France) and foreign cities (e.g., London, Tokyo, Beijing, Moscow, Cairo, Jerusalem, Berlin, Hong Kong, Rio de Janeiro, and Toronto).

c) Attributes of major cultural regions, including continents and subcontinents (e.g., Latin America, East Asia, Africa south of the Sahara, South Asia, the Middle East and North Africa, Western Europe, and Oceania).

d) Areas of high and low population densities.

e) Areas of high and low economic development.

Human Impact on the Environment

Understanding the **human impact on the environment** involves learning about the physical and social forces that precede environmental change. It includes understanding the causes and effects of population growth and migration and the ways in which these variables influence the appearance of the landscape. Among the areas of primary interest are the environmental changes generated by agriculture and the growth of cities, resource extraction, and manufacturing, as well as the relevance of these environmental effects to international and domestic policies and relationships.

Understanding the benefits, costs, and risks of environmental modification is also particularly important as the world becomes more densely populated and urbanized. Most environmental modifications have resulted in countless benefits for humans, such as expanded supplies of food and water. But sometimes human impact on environmental systems results in undesirable consequences, such as increased pollution, declines in land productivity, and extensive erosion. Excessive amounts of acid rain, the destruction of the ozone layer, and deforestation in the tropics are examples of recent adverse effects. Students should have an understanding of both the benefits and costs of human activity in order to participate intelligently in future decisions concerning environmental modification.

Finally, students need to be aware of the relationship between cultural perceptions and the consequences of environmental change, because these have a bearing on such issues as preservation of the wilderness, the development and uses of different sources of energy, the management of urban sprawl, uses of land, and the preservation of other cultures and patterns of life.

Students should be able to understand:

a) The causes and effects of changes in population structure (e.g., improvement in health care, redefinition of women's roles and family structure, cultural values, government and religious policies, and economics).

b) The effects of agricultural activity on the shape, appearance, and quality of the landscape (e.g., deforestation, terracing, grazing, irrigation, erosion, and chemical runoff of fertilizers, insecticides, and herbicides).

c) The effects of cities on the environment (e.g., climate, air and water quality, loss of farm land, solid waste and sewage disposal, flood control, and residential amenities).

d) The effects of resource extraction and manufacturing on the environment (e.g., air and water pollution, and toxic waste).

e) The economic and social costs of environmental change, as well as the benefits.

f) The relationships between cultural perceptions and environmental change (e.g., attitudes toward wilderness, land use, convenience of highways, nuclear power, and coal, and oil-fired generating plants).

Influence of Environment on Human Activity

People of different cultures must adapt to varying environmental conditions (e.g., climatic extremes and physical barriers to migration). Within this subdiscipline of cultural geography, students should be aware of the ways in which various cultures have used environmental resources available in their areas, and the influence of these patterns of use on economic activity and population.
Students should be able to understand:

a) The influence of climate, soil, vegetation, and resources on population distributions (e.g., settlement patterns) and economic activity, and the concepts of relative and absolute location.

b) The changing influence of environmental features over time as a result of physical processes (e.g., vulcanism and climate), past human efforts (e.g., railroads and canals), and recent technological innovations (e.g., automobiles and airplanes).

Spatial Interactions

Because geography is so profoundly concerned with the interaction of people and places, the concept of **spatial interaction** is central to the study of cultural geography. It includes the forces that promote or inhibit human migration, as well as the flow of commodities and the movement of resources. These forces have a strong influence on the location of cities and the patterns of settlement within cities, creating predictable arrangements of population and land use.

Students should be aware that the interactions among people, and between people and places, create networks that facilitate the flow of cultural traditions, ideas, and innovations within society; and that physical territories shape these human interactions, influencing patterns of landscape use, politics, and worldwide economic development.

Students should be able to understand:

a) The factors that promote and inhibit human migration (e.g., wars and calamities; environmental features; political, social, and economic factors; life-cycle moves; and shrinking world or "global village" perception).

b) The factors that facilitate commodity flow (e.g., economic, social, and political structures; resource availability and needs).

c) The distribution of people in cities and the reasons and consequences of urban land-use patterns (e.g., neighborhoods, ghettos, central business districts, urban fringes, manufacturing areas, retail-mall developments, urban renewal, crime and deterioration, cultural centers, residential amenities, and use of vertical space).

d) The patterns of suburban development and associated commuting patterns (e.g., automobiles, tract developments, freeways, and public transportation).

e) The factors that promote and inhibit the dissemination, adoption and rejection of new ideas, innovations, and products and the consequences of cultural diffusion (e.g., fads, changing communication technologies, consumer preferences, socio-

The National Mathematics Curriculum in England and Wales

STATUTORY INSTRUMENTS

1989 No.

EDUCATION, ENGLAND AND WALES

The Education (National Curriculum) (Attainment Targets and Programmes of Study in Mathematics) Order 1989

Made - - - - -	*March 1989*
Laid before Parliament	*March 1989*

Coming into force in accordance with articles 2 to 5

Whereas the National Curriculum Council, after due consultation, submitted to the Secretary of State and published its report on a proposal to make this Order which he had referred to it, in accordance with section 20(2) to (4) of the Education Reform Act 1988(**a**);

And whereas the Secretary of State had given notice of the said proposal to the Curriculum Council for Wales and to all other persons with whom consultation appeared to him desirable, in accordance with section 21(2) of the said Act;

And whereas the Secretary of State, in accordance with subsection (5) of the said section 20, and subsection (3) of the said section 21, duly published a draft of this Order and the other documents mentioned in those subsections and sent copies of them to the said Councils and to each of the persons consulted by them, and allowed a period of not less than one month for the submission of evidence and representations;

And whereas that period has now expired:

Now therefore the Secretary of State for Education and Science, as respects England, and the Secretary of State for Wales, as respects Wales, in exercise of the powers conferred on the Secretary of State by section 4(2)(a) and (b) and (4) of the Education Reform Act 1988 hereby make the following Order in the terms of the said draft with modifications(**b**):

Citation, commencement and interpretation

1.—(1) This Order may be cited as the Education (National Curriculum) (Attainment Targets and Programmes of Study in Mathematics) Order 1989 and shall come into force in accordance with articles 2 to 5.

(**a**) 1988 c.40.

(**b**) The modifications are to the commencement provisions. The title of the associated Document has also been changed.

(2) In this Order –

"the Document" means the document published by Her Majesty's Stationery Office entitled "Mathematics in the National Curriculum"(a);

references to the first, second, third and fourth key stages are references to the periods set out in paragraphs (a) to (d) respectively of section 3(3) of the Education Reform Act 1988;

references to levels of attainment are references to the levels set out in the Document in relation to each attainment target; and

references to ranges of levels of attainment are references to the range of levels of attainment specified for pupils of different abilities and maturities in respect of the key stage in question.

2. The provisions of this Order relating to the first key stage shall come into force –

(a) on 1st August 1989 in respect of pupils in the first year of that key stage who have attained the age of five years by that date and who do not have a statement of special educational needs; and

(b) on 1st August 1990 in respect of all other pupils.

3. The provisions of this Order relating to the second key stage shall come into force –

(a) on 1st August 1990 in respect of pupils in the first year of that key stage;

(b) on 1st August 1991 in respect of pupils in the second year of that key stage;

(c) on 1st August 1992 in respect of pupils in the third year of that key stage; and

(d) on 1st August 1993 in respect of all other pupils.

4. The provisions of this Order relating to the third key stage shall come into force –

(a) on 1st August 1989 in respect of pupils in the first year of that key stage who do not have a statement of special educational needs;

(b) on 1st August 1990 in respect of pupils in the first year of that key stage who have a statement of special educational needs and in respect of pupils in the second year of that key stage; and

(c) on 1st August 1991 in respect of all other pupils.

5. The provisions of this Order relating to the fourth key stage shall come into force –

(a) on 1st August 1992 in respect of pupils in the first year of that key stage; and

(b) on 1st August 1993 in respect of all other pupils.

Specification of attainment targets and programmes of study

6. It is hereby directed that the provisions relating to attainment targets and programmes of study set out in the Document shall have effect as provided in Articles 7 to 9 hereof for the purposes of specifying in relation to mathematics –

(a) attainment targets; and

(b) programmes of study.

7.—(1) Schedule 1 has effect in accordance with paragraph (2) for specifying the attainment targets (including the ranges of levels of attainment) for each key stage.

(2) The attainment targets described in the Document and set out in column 2 of Schedule 1 to this Order are specified in relation to the key stages set out beside them in column 1 of that Schedule, the levels applicable being those appropriate to the different abilities and maturities of the pupils being taught.

8.—(1) Schedule 2 has effect in accordance with paragraph (2) for specifying the programmes of study (including the range of levels of attainment) for each key stage.

(a) ISBN 0 11 270066 5.

(2) The programmes of study described in the Document and set out in column 2 of Schedule 2 to this Order are specified in relation to the key stages set out beside them in column 1 of that Schedule, the levels applicable being those appropriate to the different abilities and maturities of the pupils being taught.

9. The examples printed in italics in the Document (which serve to illustrate the attainment targets and programmes of study therein described) do not form part of the provision made by this Order.

SCHEDULE 1

Article 7

SPECIFICATION OF ATTAINMENT TARGETS

(1) *Key stages*	(2) *Attainment targets*
First key stage	Attainment targets 1–6 and 8–14; levels 1–3, where specified in the Document.
Second key stage	Attainment targets 1–14; levels 2–6, where specified in the Document.
Third key stage	Attainment targets 1–14; levels 3–8, where specified in the Document.
Fourth key stage	Attainment targets 1–14; levels 4–10, where specified in the Document.

SCHEDULE 2

Article 8

SPECIFICATION OF PROGRAMMES OF STUDY

(1) *Key stages*	(2) *Programmes of study (as described in the Document)*
First key stage	Levels 1 to 3.
Second key stage	Levels 2 to 6.
Third key stage	Levels 3 to 8.
Fourth key stage	Levels 4 to 10.

Secretary of State for Education and Science

Secretary of State for Wales

EXPLANATORY NOTE

(This note is not part of the Order)

Section 4(2) of the Education Reform Act 1988 places a duty on the Secretary of State to establish the National Curriculum by specifying appropriate attainment targets, programmes of study and assessment arrangements for each of the foundation subjects.

Section 4(4) allows for such an Order, instead of containing the provisions to be made, to refer to provisions in a Document published by Her Majesty's Stationery Office and to direct that those provisions shall have effect according to the Order.

This Order accordingly refers to "Mathematics in the National Curriculum" and provides for the attainment targets and programmes of study set out in it to have effect for the four key stages of a pupil's compulsory schooling. The Document sets out up to ten levels in respect of attainment targets to cover the full range of abilities and maturities of pupils of compulsory school age; the Order accordingly specifies as part of each attainment target the appropriate range of attainment levels.

The Order further provides that any examples printed in italics in the Document are for illustrative purposes only, and do not form part of the Order.

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Attainment targets and associated statements of attainment: key stages 1-4

Schedule 1 to the Education (National Curriculum) (Attainment Targets and Programmes of Study in Mathematics) Order 1989 specifies the levels applicable to pupils in each of key stages 1-4.

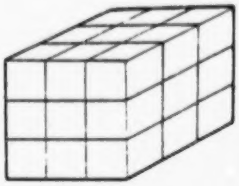
The attainment targets are set out in the groupings which will be used for reporting purposes.

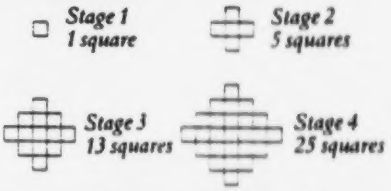
The examples printed in italics serve to illustrate the attainment targets and are non-statutory.

Attainment Target 1: Using and applying mathematics

Pupils should use number, algebra and measures in practical tasks, in real-life problems, and to investigate within mathematics itself.

Pupils should:

LEVEL	STATEMENTS OF ATTAINMENT	EXAMPLE
1	• use materials provided for a task.	*Compare objects to find which is the longest, tallest, etc.*
	• talk about own work and ask questions.	*Talk about a set of objects being compared; ask questions such as: 'Which is the longest pencil?'*
	• make predictions based on experience.	*Use a balance to compare objects; predict which of two objects will be the heavier.*
2	• select the materials and the mathematics to use for a task.	*Use handspans to measure the length of a table.*
	• describe current work, record findings and check results.	*Devise stories for adding and subtracting numbers up to 10 and check with a calculator or apparatus.*
	• ask and respond to the question: 'What would happen if...?'	*Predict whether the contents of a cylinder will fill a cylinder of different dimensions.*
3	• select the materials and the mathematics to use for a task; check results and consider whether they are sensible.	*Estimate the distance around the school hall; select appropriate method for measuring and units to be used; measure and compare the results.*
	• explain work being done and record findings systematically.	*Sketch a plan of the school hall and enter measurements made.*
	• make and test predictions.	 *Predict the number of cubes needed to construct this figure and test the prediction.*

LEVEL	STATEMENTS OF ATTAINMENT	EXAMPLE
4	- select the materials and the mathematics to use for a task; plan work methodically.	*Devise a seating plan for a school concert using a system of coordinates for numbering tickets.*
	- record findings and present them in oral, written or visual form as appropriate.	*Explore the last digits of the multiples of various numbers:* $\underline{8}, 1\underline{6}, 2\underline{4}, 3\underline{2}, 4\underline{0}, 4\underline{8}, \ldots$; *record and present the results.*
	- use examples to test statements or definitions.	*Test the statement: 'If you add the house numbers of three houses next to one another you always get a multiple of 3', for various examples:* $34 + 36 + 38 = 108 = 3 \times 36$ $81 + 83 + 85 = 249 = 3 \times 83$
5	- select the materials and the mathematics to use for a task; check there is sufficient information; work methodically and review progress.	*Design a board game that makes use of coordinates in all four quadrants.*
	- interpret mathematical information presented in oral, written or visual form.	*Use bus and train timetables to plan a journey.*
	- make and test simple statements.	*Explore the results of multiplying together the house numbers of adjacent houses* (*eg.* $6 \times 4 = 24$ $7 \times 9 = 63$ $8 \times 10 = 80$ $5 \times 7 = 35$); *make a statement about the results and check using a calculator.*
6	- design a task and select appropriate mathematics and resources; check there is sufficient information and obtain any that is missing; use 'trial and improvement' methods.	*Design and make a device to measure accurately a given period of time, e.g. two minutes.*
	- use oral, written or visual forms to record and present findings.	*Plot Cartesian coordinates to represent simple function mappings:* $x \rightarrow 2x + 3$, (*or* $y = 2x + 3$).
	- make and test generalisations and simple hypotheses; define and reason in simple contexts with some precision.	*Explore the pattern:*  Stage 1 1 square Stage 2 5 squares Stage 3 13 squares Stage 4 25 squares *Use the difference method to extend the pattern; determine a rule for the sequence and test the rule.*

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LEVEL	STATEMENTS OF ATTAINMENT	EXAMPLE
7	• devise a mathematical task; work methodically within an agreed structure; use judgement in the use of given information; use 'trial and improvement' methods; review progress.	*Design a container from a rectangular sheet of card so as to maximise the capacity of the container.* [illegible]
	• follow a chain of mathematical reasoning, spotting inconsistencies; follow new lines of investigation using alternative approaches.	*[illegible] decimal representation of [illegible] different [illegible] of [illegible] about [illegible] such as '1/13 has a cycle of six repeating digits'.*
8	• devise a mathematical task and make a detailed plan of the work; work methodically, checking information for completeness; consider whether the results are of the right order.	*Decide where to put a telephone box in the locality.*
	• make statements of conjecture using 'if ... then ...'; define, reason, prove and disprove.	*In exploring decimals and fractions with a calculator or microcomputer make statements of the type, 'If the denominator has prime factors other than 2 or 5, then the decimal will recur'; offer justifications, explanations and proofs of such statements.*
9	• design, plan and carry through a mathematical task to a successful conclusion.	*Design a wire frame lampshade with the design showing clearly the length of wire and area of material required.*
	• state whether a conjecture is true, false or not proven; define and reason; prove and disprove and use counter-examples; use symbolisation; recognise and use necessary and sufficient conditions.	*Devise and test a statement about the minimum surface area for a cylinder of fixed volume.*

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LEVEL	STATEMENTS OF ATTAINMENT	EXAMPLE
10	• design, plan and carry through a mathematical task to a successful conclusion; present alternative solutions and justify selected route.	*Investigate and design traffic light and 1-way systems for a city centre, given the street plan and traffic flows; present an analysis of the effects of the systems and suggest a best solution.*
	• give definitions which are sufficient or minimal; use symbolisation with confidence; construct a proof including proof by contradiction.	*Rearrange the equation* $x^3-5x+3=0$ *to obtain the iterative formula* $x_{n+1}=\frac{(x_n^3+3)}{5}$ *and test whether it converges or diverges for different initial values of x.*

Knowledge, skills, understanding and use of number, algebra and measures (ATs 1-8).

Attainment Target 2: Number

• •

Pupils should understand number and number notation.

LEVEL	STATEMENTS OF ATTAINMENT	EXAMPLE
	Pupils should:	
1	• count, read, write and order numbers to at least 10; know that the size of a set is given by the last number in the count.	
	• understand the conservation of number.	*Know that if a set of 8 pencils is counted, the answer is always the same however they are arranged.*
2	• read, write and order numbers to at least 100; use the knowledge that the tens-digit indicates the number of tens.	*Know that 37 means 3 tens and 7 units; know that three 10p coins and four 1p coins give 34p.*
	• understand the meaning of 'a half' and 'a quarter'.	*Find a quarter of a piece of string; know that half of 8 is 4.*
3	• read, write and order numbers to at least 1000; use the knowledge that the position of a digit indicates its value.	*Know that 'four hundred and two' is written 402 and why neither 42 nor 4002 is correct.*
	• use decimal notation as the conventional way of recording in money.	*Know that three £1 coins plus six 1p coins is written as £3·06, and that 3·6 on a calculator means £3·60 in the context of money.*
	• appreciate the meaning of negative whole numbers in familiar contexts.	*Read a temperature scale; understand a negative output on a calculator.*
4	• read, write and order whole numbers.	
	• understand the effect of multiplying a whole number by 10 or 100.	*Explain why the cost of 10 objects costing £23 each is £230.*
	• use, with understanding, decimal notation to two decimal places in the context of measurement.	*Read scales marked in hundredths and numbered in tenths (1·89 m).*
	• recognise and understand simple everyday fractions.	*Estimate $\frac{1}{3}$ of a pint of milk or $\frac{3}{4}$ of the length of a piece of wood.*
	• recognise and understand simple percentages.	*Know that 7 books out of a total of 100 books represents 7%.*
	• understand and use the relationship between place values in whole numbers.	*Know that 5000 is 5 thousands or 50 hundreds or 500 tens or 5000 ones.*

LEVEL	STATEMENTS OF ATTAINMENT	EXAMPLE
5	• use index notation to express powers of whole numbers.	*Know that* $2^5 = 2 \times 2 \times 2 \times 2 \times 2$.
	• use unitary ratios.	*Use a ratio of 1:50 for drawing a plan of the classroom.*
6	• read, write and order decimals; appreciate the relationship between place values.	*Explain that 0·23 is 2 tenths and 3 hundredths or 23 hundredths.*
	• understand and use equivalence of fractions and of ratios; relate these to decimals and percentages.	*Know that* $\frac{2}{5} = \frac{4}{10} = 0{\cdot}4 = 40\%$. *State that lengths 8 cm and 12 cm in a drawing are in the ratio 2:3.*
7	• express a positive integer as a product of primes.	*Express 147 as* $3 \times 7 \times 7$ *or* 3×7^2. *Find the HCF (Highest Common Factor) and LCM (Lowest Common Multiple) of two whole numbers.*
8	• express numbers in standard index form using positive and negative integer powers of 10.	*Know that 1 million* $= 10^6$ *and* $22731 = 2{\cdot}2731 \times 10^4$.
	• use index notation to represent powers and roots.	*Use the* x^y *key on a calculator.*
9	• distinguish between rational and irrational numbers.	*Know that* $\sqrt{2}$ *and* π *are irrational. Know the significance of recurring and non-recurring decimals in this context.*
10	• use the knowledge, skills and understanding attained at lower levels in a wider range of contexts.	

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LEVEL 1

PROGRAMME OF STUDY

To achieve level 1 within the attainment targets pupils should be:

Using and applying mathematics	• using materials for a practical task. • talking about own work and asking questions. • making predictions based on experience.
Number	• counting, reading, writing and ordering numbers to at least 10. • understanding conservation of number. • using addition and subtraction with numbers no greater than 10, in the context of real objects. • making a sensible estimation of a number of objects up to 10.
Algebra	• copying, continuing and devising repeating patterns.
Measures	• comparing and ordering objects without measuring; using appropriate language.
Shape and space	• sorting and classifying 2-D and 3-D shapes. • building 3-D solid shapes and drawing 2-D shapes and describing them. • using common words to describe a position. • giving and understanding instructions for movement along a line.
Handling data	• selecting criteria for sorting a set of objects, and applying them consistently. • recording with objects or drawing. • creating simple mapping diagrams showing relationships and interpreting them. • recognising possible outcomes of random events.

LEVEL 2

PROGRAMME OF STUDY

To achieve level 2 within the attainment targets pupils should be:

Using and applying mathematics

- selecting the materials and the mathematics to use for a practical task.
- describing work and checking results.
- asking and responding to the question: 'What would happen if . . . ?'

Number

- reading, writing and ordering numbers to at least 100 and using the knowledge that the tens digit indicates the number of tens.
- understanding the meaning of 'half' and 'quarter'.
- knowing and using addition and subtraction facts up to 10.
- comparing two numbers to find the difference.
- solving whole number problems involving addition and subtraction, including money.
- making a sensible estimate of a number of objects up to 20.

Algebra

- exploring and using patterns in addition and subtraction facts to 10.
- distinguishing odd and even numbers.
- understanding the use of a symbol to stand for an unknown number.

Measures

- using non-standard measures in length, area, volume, capacity, 'weight' and time, comparing objects and recognising the need for standard units.
- using coins in simple contexts.
- knowing commonly used units in length, capacity, 'weight' and time.

Shape and space

- recognising squares, rectangles, circles, triangles, hexagons, pentagons, cubes, rectangular boxes (cuboids), cylinders and spheres and describing them.
- understanding the notion of angle.
- understanding turning through right-angles and recognising right-angled corners.
- recognising types of movement: straight (translation), turning (rotation) and flip (reflection).

Handling data

- choosing criteria to sort and classify objects: recording results or outcomes of events.
- designing a data collection sheet, recording data leading to a frequency table.
- constructing and interpreting frequency tables and block graphs.
- using diagrams to represent the result of classification using two different criteria.
- recognising a degree of uncertainty about the outcomes of some events and that other events are certain or impossible.

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LEVEL 10

PROGRAMME OF STUDY

To achieve level 10 within the attainment targets pupils should be:

Using and applying mathematics

- designing, planning and carrying through a mathematical task to a successful conclusion; presenting alternative solutions and justifying selected route.
- giving definitions which are sufficient or minimal.
- using symbolisation with confidence; constructing a proof including proof by contradictions.

Number

- calculate the upper and lower bounds in the addition, subtraction, multiplication and division of numbers expressed to a given degree of accuracy.
- using the knowledge, skills and understanding attained at lower levels in a wider range of contexts.

Algebra

- using a calculator or computer to investigate whether a sequence given iteratively converges or diverges.
- manipulating a range of algebraic expressions in a variety of contexts.
- constructing tangents to graphs to determine the gradient.
- finding the approximate area between a curve and the horizontal axis between two limits, and interpreting the result.
- sketching the graph of functions derived from other functions.

Measures

- determining the possible effects of error on calculations involving measurements.

Shape and space

- knowing and using angle and tangent properties of circles.
- sketching the graphs of sine, cosine and tangent functions for all angles.
- generating trigonometric functions using a calculator or computer and interpreting them.
- using sine and cosine rules to solve problems including simple cases in 3-D.
- understanding how transformations are related by combinations and inverses.
- using matrices to define transformations in 2-D.

Handling data

- describing the range of a variable using different measures of dispersion; calculating standard deviation of a set of data.
- interpreting various types of diagrams such as those used in analysis of critical path and linear programming.
- considering different shapes of histograms representing distributions with special reference to mean and dispersion, including the **normal** distribution.
- understanding the probability for any two events happening.

APPENDIX A

FLORIDA DEPARTMENT OF EDUCATION
Betty Castor
Commissioner of Education

Larry D. Hutcheson, Chief
Bureau of Program Support Services
Division of Public Schools

November 14, 1991

Mr. Paul Barton
Educational Testing Service
Policy Information Center
Princeton, NJ 08451

Dear Paul:

This is in response to your request that I provide some comments about the use of the term "educational standards." I am pleased to do so and hope that my thoughts will be useful.

The term "educational standard" seems to be a favorite one these days. I have seen the term used in three separate ways: (1) as a statement of student expectations, (2) as a statement of criterion or level of performance, and (3) as a statement of intent or desirable characteristics. Each will be illustrated below.

1. A standard as a statement of student expectations.

   In 1976, the Educational Accountability Act in Florida stated that the Department was to create "minimum student performance standards in the various program categories and chronological grade levels, especially in reading, writing, and mathematics..." Thus, for years we talked about our student performance standards which were, in reality, nothing more than broadly stated student objectives.

   Several years ago, Florida initiated the District Quality Instruction Incentives Program which was designed to provide an avenue for merit pay to flow to instructional staff. Each school could establish improvement goals and, if their goals were accomplished, bonus money would flow to the school. The authorizing legislation included language which said that a school could select a standard or standards from four categories including tests, participation in activities, achievement, and discipline. Thus, the school would create a performance improvement objective which was called a "standard" and work toward its accomplishment.

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2. A standard as a statement of criterion or level of performance.

The 1976 accountability law stated that the Department would "...monitor the results of the assessment program and, at any time the composite student performance of a school or basic program is found to be below the established minimum standards, notify the district superintendent, ..." In this context, a standard was a numerical index number which reflected a desirable vs. undesirable level of student performance. Schools worked very hard to get their students' academic proficiency high enough to be above this criterion level.

In State Board of Education Rule 6A-10.0312, FAC the Board defined the passing requirements for the College-Level Academic Skills Test (CLAST). Students are required to pass this test before receiving an associate in arts or baccalaureate degree. The passing scores are referred to as "minimum standards" in the rule.

Section 240.233, Florida Statutes lists the minimum admission standards for admission to a state university. These include, among other things, that each student will have completed "two credits of sequential foreign language at the secondary level..."

3. A standard as a statement of intent or desirable characteristics.

The Standards for Teacher Competence in Educational Assessment of Students developed by the American Federation of Teachers, the National Council on Measurement in Education, and the National Education Association use the term standard in this way. This document includes such standards as, "Teachers should be skilled in choosing assessment methods appropriate for instructional decisions." This is a general statement of intent (philosophy or ideal?) which is definitely not in the same spirit as saying that the passing score for a test is a score of 200, for example.

The National Council of Teachers of Mathematics (NCTM) in its popular and widely discussed paper Curriculum and Evaluation Standards for School Mathematics uses standards similarly. For example, standard 8 states that, "In grades 5 - 8, the mathematics curriculum should include the study of number systems and number theory so that students can understand and appreciate the need for numbers beyond the whole numbers ..." Their draft report Professional Standards for Teaching Mathematics includes standards for mathematics teachers which are written in the same style.

In Florida, the document titled Standards and Supporting Data for Teacher Education Program Approval in the State of Florida includes standards of intent such as, "The Teacher Education Program responds to needs projected for 21st century Florida teachers. The philosophy which guides program design and the objectives which define program content are both clearly rooted in those needs." Clearly, this is a statement of general intent.

I consulted my Webster's unabridged dictionary and found two general meanings for the word "standard." The first is that a standard is "something established by ...general consent as a model or example to be followed." The second is that a standard is "a definite level or degree of quality that is proper and adequate for a specific purpose." Thus, my working examples in set one and three illustrate the first usage while my examples in set two illustrate the second usage. Unfortunately, I suspect that many observers of the national debate over standards, national tests, NGA goals, etc. may not have observed the distinctly different uses of the word "standard," and this may be interfering with our ability to debate the issues.

I would be pleased to further explain any of my ideas if you wish. Just call or write.

Sincerely,

Tom

Thomas H. Fisher, Ed. D
Administrator
Assessment, Testing, and Evaluation Section

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